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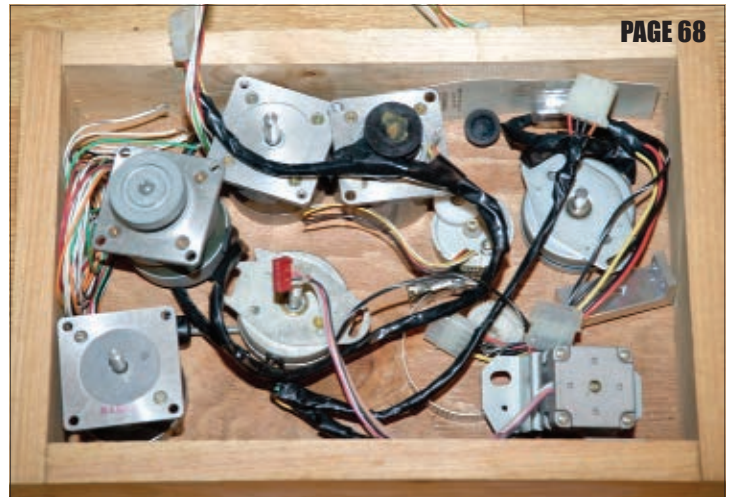


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One never visualizes hard drives and microcontrollers in the same thought process. About 10 B.M.C. (Before MicroSD Card), relatively large capacity hard drives and Intel microprocessors were the norm. These days, the MicroSD card has brought the storage capacity of yesteryear's hard drives to the microcontroller bus. Today's microcontroller can control as much data storage in the space of a couple of quarters as the first personal computers could with a full-sized hard drive.
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Mind / Iron

by Bryan Bergeron, Editor

Newly Discovered Method Of Locomotion May Have Implications In Robotics

Nature has done a great job evolving creatures to move efficiently on the land, in the sea, and in the air. It's one of the reasons biomimetics – the science of mimicking nature – is a popular basis for robotics R&D. As I've noted in previous editorials, one of the most fascinating and challenging areas of robotic work is in developing 'soft' robots.

A robot that can squeeze through a small opening and deliver aid or at least communications to someone trapped under rubble has obvious advantages over, say, a crawler that can at best only scurry on top of the rubble. Similarly, a robot that can squeeze under a door and deliver a lethal gas or other payload to the occupants has obvious appeal to the Department of Defense. However, to date, there haven't been any clear winners in the field of soft robots. Sure, in Japan it's common to wrap the angled metal and protrusions on robots with layers of soft foam to prevent injury to humans. And there's at least one self-deforming wheel that can roll and jump over modest obstacles – with the caveat that power and processing are supplied externally [Hiri].

What has the soft robotics field abuzz is the publication of *Visceral-Locomotory Pistoning in Crawling Caterpillars* in July 2010 by scientists at Tufts University and Virginia Tech [Simon]. Based on phase-contrast xray imaging – which you can view on the web – the researchers determined that the green tobacco hornworm caterpillar pumps its internal organs as part of the propulsion process. This is a new form of propulsion that may have a direct bearing on the future of soft robotics. As of this editorial, no group has come forward with a robot that copies this rather odd form of propulsion, but I assume several labs are working feverishly on the challenge. I also don't doubt that the patent office has a few related patents in their inbox. So, what's there to do as a robotics enthusiast, other than wait for the academic labs to secure funding and government grants? Well, soft robotics isn't limited to the well-to-do. You can go soft in any number of ways – from using memory wire to pneumatics. I suggest pneumatics. And you needn't work on the microscopic scale. A foot-long caterpillar model with at least one internal bladder should do. You'll have to study the videos posted online and then work to mimic the motion of the internal bladder of your model.

As a proof of concept, it's usually best to keep the power and processing separate from the platform. One of the advantages of using pneumatics is the simplicity of actuators or bladders in a robot. No need to worry about servos and control lines. Of course, it's not as simple as that. You have to construct the soft outer shell in a way that supports the robot and allows mobility. I suspect there's also something special going on with the caterpillar's feet. Again, you'll have to study the video. The good thing is that the videos – which are of excellent quality – are posted online.

If you manage to get something working, please send in a video or article, and we'll get the word out. **SV**

References:

Shinichi Hiri et al, *Crawling and Jumping Soft Robots*, Dept Robotics, Ritsumeikan University, Japan.
www.ritsumei.ac.jp/se/~hirai/research/softrobot-e.html.

Michael Simon et al, *Visceral-Locomotory Pistoning in Crawling Caterpillars*, Cell Biology. 22 July, 2010. You can see the abstract and video at www.cell.com/current-biology/abstract/S0960-9822%2810%2900807-9.

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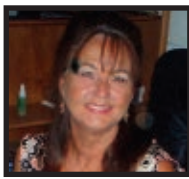
Model	6 Volts		7.4 Volts		Part#	Dimensions	Weight
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Robytes

by Jeff and Jenn Eckert

Prosthetic Limb Project Funded

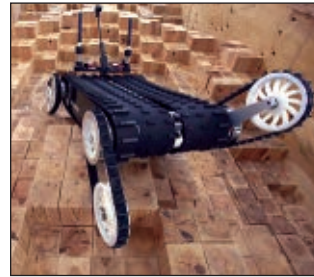


Final prototype of the Modular Prosthetic Limb.
Courtesy of DARPA/JHUAPL/HDT
Engineering Services.

Late last year, the Johns Hopkins University Applied Physics Lab (APL, www.jhuapl.edu) demonstrated the final prototype of its Modular Prosthetic Limb (MPL), developed under a four-year program sponsored by DARPA (www.darpa.gov). Apparently, the agency was impressed, because it has awarded APL another \$34.5 million to further develop the unit and test it on human subjects. The MPL offers 22 degrees of motion (including independent movement of the fingers and thumb) and weighs about 9 lbs — the same as the average natural limb. Perhaps the most impressive feature is that it's controlled by the wearer's thoughts via implanted microarrays, and it also provides feedback to the brain. Program manager Michael McLoughlin observed, "We've developed the enabling technologies to create upper-extremity prosthetics that are more natural in appearance and use. Now, in Phase 3, we are ready to test it with humans to demonstrate that the system can be operated with a patient's thoughts and that it can provide that patient with sensory feedback, restoring the sensation of touch." Within the next year, the APL team intends to install one on a real patient with a high spinal cord injury, and they plan to expand that to five over the next two years.

Rescue Bot for Earthquake Victims

Given that about 20 percent of the world's most powerful earthquakes hit Japan, it figures that the folks



Quince — a new rescue bot developed at the Chiba Institute of Technology.



who inhabit the island nation have serious concern about them. Accordingly, researchers at the Chiba Institute of Technology's Future Robotics Technology Center (www.furo.org) have developed Quince — a disasterbot designed to crawl through debris, map terrain in three dimensions, and deliver food, water, and cell phones to people trapped under quake rubble. Controlled via a game console, Quince can wander around at distances up to about 255 ft (700 m) and navigate inclines of up to 82 degrees. Using its robotic arm, Quince can also open doors, move rubble, etc., and it's fitted with a camera, and IR and CO₂ sensors that help locate survivors. Collected information is sent back to rescue workers via Wi-Fi. According to Eiji Koyanagi, Vice Director of the Center, "The 3D mapping of the disaster site gives rescuers an idea about where the victims are and which point of access gives them the best chance to save a life." The next step is to put it to work at the Chiba City fire department to see how it fares in actual rescue operations.

And Another for Drownings

Also designed to save lives is the new SARbot underwater rescue system from SeaBotix, Inc. (www.seabotix.com), vendors of the Little Benthic Vehicle (LBV) family of small underwater vehicles. The company was approached by the UK's Derbyshire Fire & Rescue unit which deals with more than 700 drownings every year. Apparently, on any given night, some overindulgent pub crawlers — while stumbling home late at night — either decide to take a dip or just fall in. They subsequently inhale water and go unconscious.



The SeaBotix SARbot™ in a simulated rescue.

Now, research has shown that if the water is no warmer than about 70°F (21°C) and the souse is dragged out within 90 minutes, he has a good chance of being revived. Fortunately, the Derbyshire crew is usually able to reach a potential victim in as little as 10 minutes. The problem is that because of strong currents and near-zero visibility they can't locate the bodies soon enough. SARbot solves the problem by incorporating a Gemini imaging sonar system, bright LED illumination, and video enhancement. It also features a set of jaws that clamp onto the individual's arm or leg to allow personnel to drag him back to shore. In field trials, it was shown that the ROV system can be deployed in less than three minutes, so we can expect that, over time, many otherwise doomed, ale-soaked Brits will live to see another opening time. I'll certainly drink to that.

Bot Swings Its Way to the Top

One of the few gymnastic exercises yours truly was ever good at is rope climbing which actually requires very little strength if you simply swing back and forth, and grab a higher place on the rope with each oscillation. Now, some engineers at the University of Utah (www.utah.edu) have employed the same concept in creating the ROCR Oscillating Climbing Robot. As described in a recent issue of *Transactions on*



Mechanical engineer William Provancher watches ROCR climb a carpeted wall. Photo by Mark Fehlberg, University of Utah.

Mechatronics, the device uses two claws, a motor, and a pendulum-like tail to crawl up an eight-foot carpeted wall in a little over 15 seconds. According to designer William Provancher, most climbing robots are designed primarily to avoid falling, and efficiency (i.e., ratio of work performed to the electrical energy consumed) is not a major consideration. ROCR, on the other hand, achieved 20 percent efficiency in climbing tests which is nearly as good as an automobile engine. Because the world doesn't contain all that many carpeted walls, ROCR probably

doesn't have much practical use. However, future work will be aimed at integrating more complex gripping mechanisms so it can also climb on such substances as brick and sandstone, as well as boosting efficiency. According to Provancher, "Higher climbing efficiencies will extend the battery life of a self-contained, autonomous robot and expand the variety of tasks the robot can perform."

Bot Exoskeleton Eliminates Wheelchairs

In the early 1990s, engineers Richard Little and Robert Irving, for some unspecified reason, left their native Scotland and emigrated to New Zealand. Because both of their mothers use wheelchairs, they had a working knowledge of the related issues and obstacles. Then, when Irving was diagnosed with MS about seven years ago, they decided to put their expertise to work to develop a better alternative. With support from a couple venture capital firms, they formed Rex Bionics (www.rexbionics.com) and developed the Rex Robotic Exoskeleton which is basically a pair of legs that allow the wearer to stand, walk, go up and down stairs, and so on via a joystick control. This is not a simple thing to accomplish; in fact, 4,700+ parts go into the package. According to neurologist Dr. Richard Roxburgh, "For many of my patients, Rex represents the first time they've been able to stand up and walk for years. There are obvious immediate benefits in terms of mobility, improved social interaction, and self-image. There are also likely to be major long-term health and quality of life benefits through reducing the complications of being in a wheelchair all the time." After the company concludes required testing, it will be marketed initially in Europe and Australia. FDA approval for US sales will come later. The hefty price tag, reportedly about \$150,000 USD, includes two weeks of training at the Rex Bionics facility in Auckland. **SV**

The Rex Robotic Exoskeleton allows wheelchair-disabled individuals to walk again.



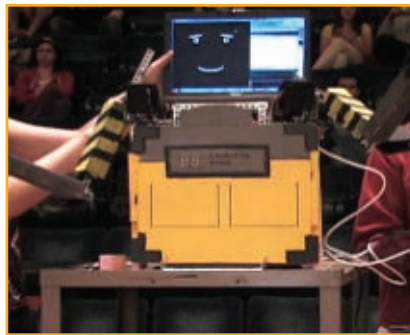


GEERHEAD

by David Geer

Contact the author at geercom@windstream.net

Baton-Wielding Bots Command and Control Orchestrated Wonders!



The College of New Jersey in Ewing received an award of \$359,477 in March '09 from the National Science Foundation (NSF) to support the Conducting Robots class for three years. The class brings together students from four disciplines — Computer Science, Mechanical Engineering, Interactive Multimedia, and Music — to design, build, and program robots capable of conducting orchestras. The class culminates in a performance where the robot conducts the TCNJ orchestra on brief musical pieces.

Under the NSF's CreativeIT Program, the college receives funding to explore synergistic cross-disciplinary research combining computer science and creativity. The course teams students from the varying disciplines to pool their resources and come up with robotic systems that conduct the orchestra. The systems include multimedia displays. "In essence, the students will create a robotic maestro that mimics the arm movements and facial expressions of a human conductor at work," according to a TCNJ media release. The robotic system is a mode for teaching the students not only about their own areas of expertise but how to cooperate technically with other disciplines in order to awaken or enhance their creativity.

During a recent semester, students in the Conducting Robots course constructed three robots. Chris Ault, associate professor of Interactive Multimedia; Dr. Teresa Nakra, associate professor of Music; Dr. Andrea Salgian, assistant professor of Computer Science; and Dr. Jennifer Wang, associate professor of Mechanical Engineering taught the class. Seventeen students took the course and made up three teams of roboticists.

Requirements included that the robots use both visualization and mechanical motion to communicate cues and instructions on tempo, dynamics, and articulation to the orchestra.

There has been little attempt by roboticists to date to create robots to conduct orchestras. A couple exceptions were Honda's ASIMO robot conducting the Detroit Symphony in 2008, and Honda's QRIO that conducted the Tokyo Philharmonic Orchestra for 90 seconds in March '04. However, the robot's pre-coded activity did not include true interaction with the musicians in the orchestra.

The TCNJ students were provided with the input from MIDI files. This and visual analysis helped to give the robots more human-like gestures. The robots were able to convey more information than ASIMO.

ACRE Robot

The ACRE or Automated Conducting Robot Experience robot is a human size robot. The team built it with an upper frame and a lower frame to simulate the human torso and legs, respectively. The upper frame consists of three plates used to accommodate a laptop, a monitor (to simulate the conductor's face), and other necessary equipment. The arms were connected to the top plate, or shoulder plate. The team made the frame of aluminum 6061 for its strength, rigidity, and ease of use.

Since the robot's right arm keeps the tempo, its movement is on a fixed path that can be achieved with only three degrees of freedom: two in the shoulder joint and one in the elbow joint. There is a gripper at the end of the right arm for a hand.

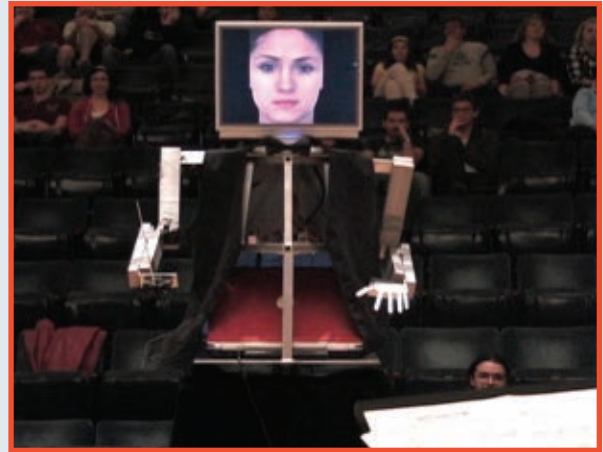
The left arm has two degrees of freedom (more can be added) and is used to indicate cueing and volume control to the orchestra.

Each arm motor is a Hitec HSR-5990TG servo motor. The team selected this motor because it provided enough torque to enable the necessary arm capabilities given the arm's weight and other factors. The gripper is a Lynxmotion Little Grip servo motor.

An Arduino Duemilanove was used for the arm's motor controller. The team chose it for its open source platform which made it easy for team members to select and write code for the necessary functions. The Arduino was programmed in Processing — a programming language that is an extension of the Java language.

The lower body is a rectangular frame design with four

ACRE



At the recent performance of the TCNJ robot builds, the ACRE robot led a portion of music from *West Side Story* (written by Leonard Bernstein). The goal of this robotic project is to imbue the necessary traits of a human conductor so that it leads an orchestra through a given piece of music. The robot's aesthetics bridge the gap between the human and robotic worlds, combining human and robotic features, according to the roboticists at TCNJ.

The robot proffers visible, physical cues from which the orchestra takes its lead. According to the students, this robot's functions and communication modes include:

- A right arm that conducts the beat pattern.
- A left arm that indicates to each section of the orchestra when to start, stop, and increase or lower volume, and by how much.
- The robot uses simulated knee bends, actuated by a linear actuator in its lower body.
- A Hilaire-type mobile robot configuration enables hip rotation so the bot can turn in place to face different sections
- The team endowed the robot with facial expressions displayed on a flat panel monitor to indicate changes in emotion.

Resources

The College of New Jersey
www.tcnj.edu

Videos of the robotic conductors
<http://creativeit.immtcnj.com/video>

Grant aids Conducting Robots Course
www.tcnj.edu/~pa/news/2009/creativeitgrant.htm

corners and a divider in the middle. The designers built in ample space for components such as batteries and microcontrollers. From there, they designed the robot to be able to “bend at the waist” which is between this lower frame and the upper torso.

To simulate bending at the waist, the team designed the robot to make a vertical movement of up to six inches while still supporting the upper torso and mechanics. The technology used to create the movement was a linear actuator; specifically a Thompson Electrak Pro Series linear actuator.

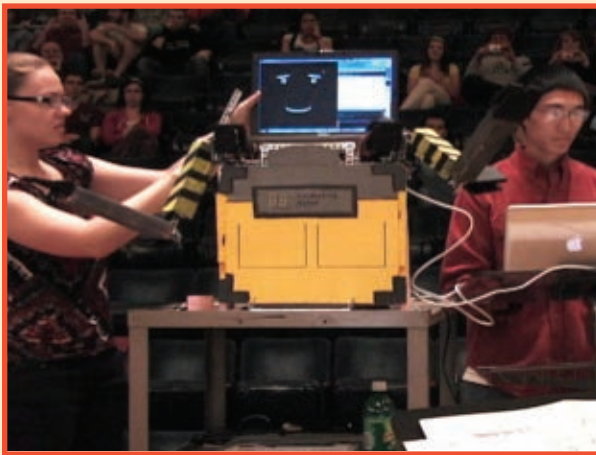
The team housed the actuator for the waist bending system in the lower frame using two pieces of aluminum

plating bolted to two pieces of angle iron, secured to the bottom of the lower frame’s top plate. A bolt running through both plates beneath the actuator holds it in place. The team covered the non-moving areas of the actuator with noise canceling foam to keep sound from spreading and reverberating in the auditorium.

The robot’s facial expressions consist of six images taken from the Bosphorus 3D Face Database and display on the monitor to indicate emotional changes. The team altered the images for brightness, background consistency (black), and facial consistency (no blemishes) so the orchestra could clearly understand and interpret the facial cues.

The robot learned the conducting movements by analyzing a video sequence of one of the students conducting the same piece of music. A video tracking system previously developed by Dr. Salgian's students was used to extract the locations of the conductor's hands. From here, the students were able to compute the required joint locations using inverse kinematics.

C4



C4 conducted a fragment from Hungarian Dance #5 by Johannes Brahms.

The C4 robot uses two humanoid robotic arms, each with three degrees of freedom. The left arm points to the particular sections of instruments in the orchestra when it was time for them to take up their parts.

The two arms indicate the beat pattern and tempo. The robot would raise and lower its left arm and increase the breadth of the movement of its right arm to indicate changes in dynamics.

The student roboticists used a software program to convert a MIDI-based musical score into something the robot could follow to guide its own movements. The robot uses a real-time audio processing capability to listen to the orchestra and respond to its efforts. “If the orchestra was performing differently than the robot was conducting, the system sent interrupts to the microprocessor to change the robotic motion to adjust the orchestra,” the students said.

The robot’s head was a display with a smiley face that smiled when the orchestra played well, and took on a serious or sad face if the orchestra was not performing at its best.

C4 Robot

This robot — a comparable three degrees of freedom two arm robot — is half human size and was built using the VEX robotics kit. It is also controlled by the Arduino microcontroller.

Two-dimensional cartoon faces represent the robot’s facial expressions. The team selected cartoon faces for their simplicity, familiarity and because they would not seem too human for a robot, thus avoiding the uncanny valley phenomenon (www.popularmechanics.com/technology/engineering/robots/4343054).

The team covered the arms and body with yellow and gray foam to beef up the body and ensure its visibility.

Instead of video analysis, this robot used annotated MIDI files and a set of standard conducting gestures to learn how to conduct a given musical piece.

C4 is the only one of the three robots that can get feedback from the orchestra. It uses Chuck — an audio programming language for real-time performance and analysis — to verify if the dynamics and tempo of the music played by the orchestra matches the one conducted.

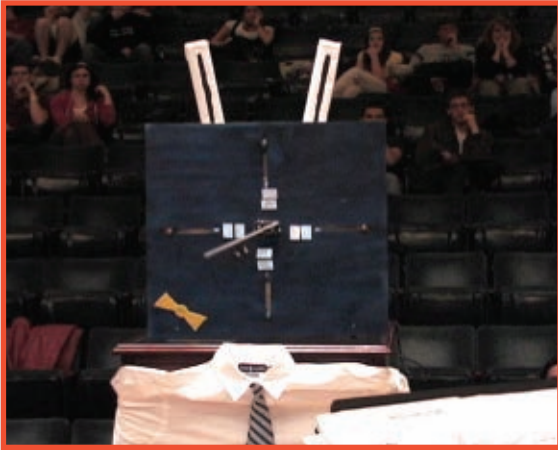
SuperConductor Robot

This conducting robot is decidedly non-human. A square, black board with a rotating baton in the center and four consecutively lighting LEDs that move away from and back to the center of the board comprise this bot.

The robot employs two motors and a circuit board to actuate the baton and lights. The board is a BASIC Stamp. A bicycle hub and lever attached to one of the motors actuates the four levers attached to the LED lights.

The motors are a Parallax standard servo and a continuous servo.

SuperConductor



SuperConductor directed an original piece titled *SuperPiece*, composed by Brett Taylor – one of the students on the SuperConductor team.

This non-humanoid conducting robot is a square board with four LED lights. The conductor's baton lies in the center of the board. The baton rotates clockwise around the face of the board. The LEDs light up as the baton passes a metallic fabric across their circuits in order, temporarily completing each of those electric circuits.

A four-armed contraption rotates independent of the LED lights behind the conductor's face. As the arms rotate, the LEDs move closer to and then farther away from the center of the board. All the movements correspond to the tempo changes and dynamics of the music.

Final Notes

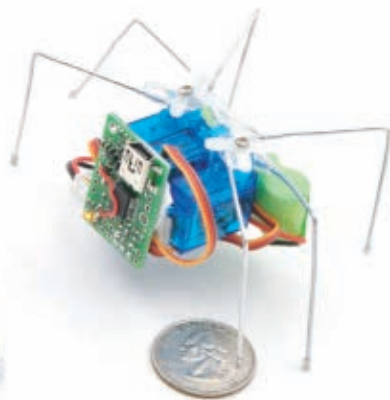
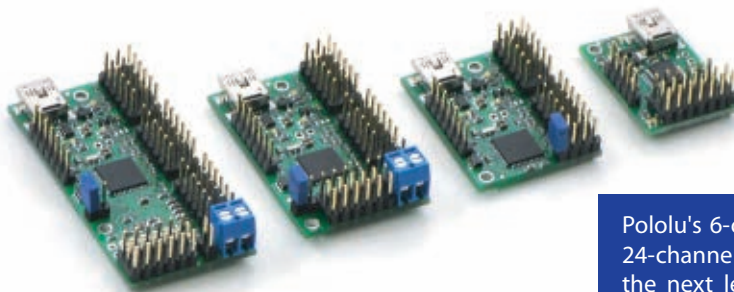
The students involved in the Conducting Robots course truly orchestrated three original builds, all accomplishing the

task at hand. It is amazing how students from different disciplines can come together to innovate. Truly music to the future's ears.

The robots conducted their pieces in April of this year. **SV**

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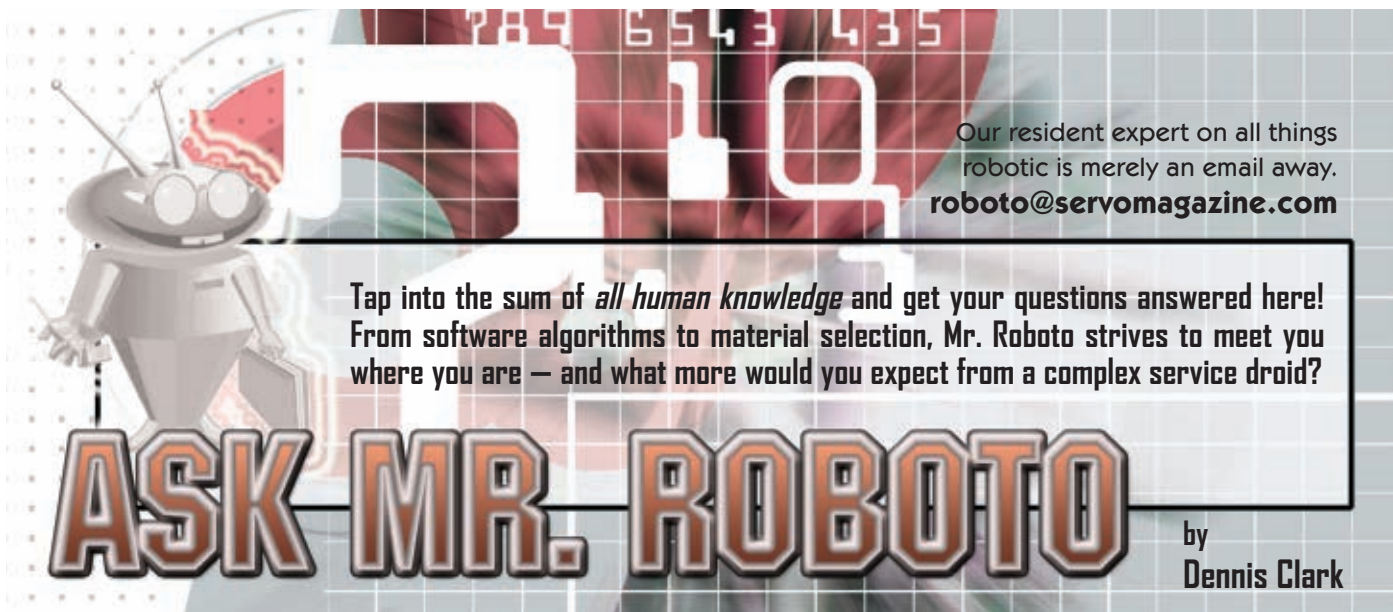
Pololu's 6-channel Micro Maestro and new 12-, 18-, and 24-channel Mini Maestros take serial servo controllers to the next level by incorporating native USB control for easy connection to a PC and programmability via a simple scripting language for self-contained, host controller-free applications. Whether you want the best servo controller available or a versatile, general-purpose I/O control board, these compact devices will deliver.

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\$49.95

#1354
Mini Maestro
18-Channel
\$39.95

#1352
Mini Maestro
12-Channel
\$29.95

#1350
Micro Maestro
6-Channel
\$19.95



I always like to “wind up” on a column since it seems rude to just jump into the questions. So, for my warm-up ... First LEGO League is getting ready to take off now; the kids are working on the challenge field and we are all watching the FLL site for what the challenge will actually be — it won’t be announced until, er, a month ago (as you read this column). The kids are jazzed and the field has lots of intriguing robot challenges (Heart with stent, Brain and Door – huh? Shades of “Young Frankenstein” come to mind there!) Last month, we did some NXC programming with the Mindstorms NXP robot, but this month the questions are more about basic topics. So, now that my fingers and mind are warmed up, let’s get started!

Q I want to use sound to trigger an action on my robot, but I’m not sure how to do it. Can you give me a circuit that will allow my Arduino to “hear?” Thanks!

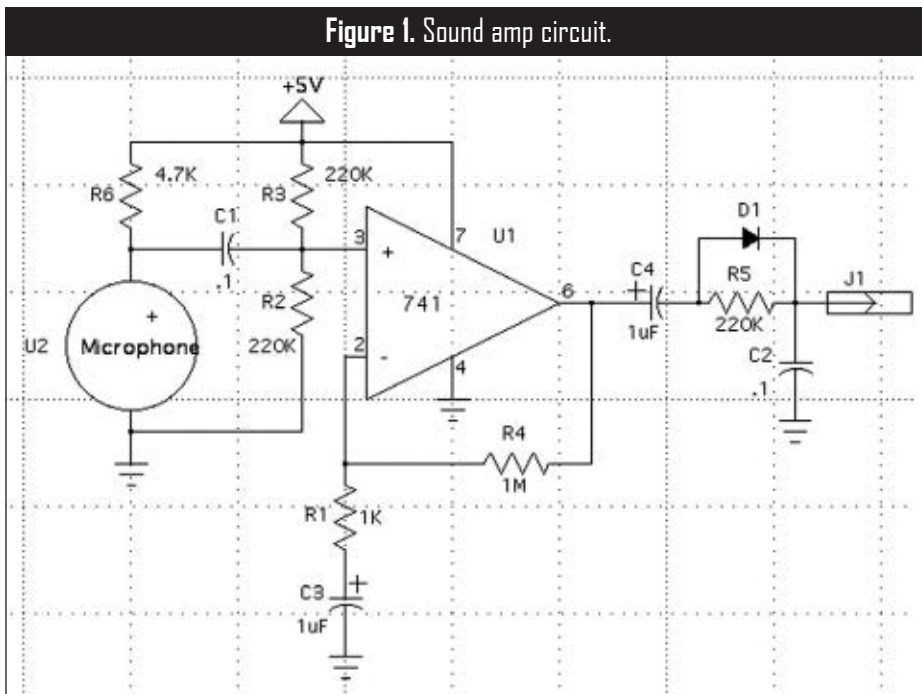
— Tony (via email)

A Let me guess, you want a start-up for your Trinity Firefighter that will score you extra points? As it turns out, this isn’t too difficult but you’ll have to get a few parts that you probably don’t normally carry in your parts bin. This simple circuit is made with an electret microphone, a 741 op-amp, and a handful of discrete parts. I’ve made this and it works, so let’s get going. **Figure 1** is the schematic for the circuit that I have in mind. I used this in a Halloween prank to make a ghost jump out when someone yelled “Trick or Treat!” one year. Lots of fun.

Any electret microphone you find will work here, such as the Digi-Key 102-1720-ND; this part wants a 2.2K bias resistor on the microphone instead of the 4.7K one that I show in my schematic. I chose the 741 op-amp because I had a bunch of them lying around and this application isn’t too picky about this. One nice thing about the 741 is that it is a single supply op-amp which means it doesn’t need a plus and minus supply; just 5V and ground works fine.

The operation of the circuit is simple. The small AC signal from the microphone appears at pin 3 of the op-amp which has been biased at 2.5V (halfway between 5V and ground) by R2 and R3. R4 and R1 set the gain (about 1,000) and C3 allows only the AC component to be amplified. The cap C4, again, passes only the AC amplified signal through to the RC accumulator circuit

Figure 1. Sound amp circuit.



formed by R5, D1, and C2. D1 encourages the signal to charge positive quickly, but discharge slowly back through the resistor. I get a voltage swing of about 2V here which is enough to trigger a microcontroller input pin. Play with R6 to set the sensitivity level of the microphone to suit you.

This circuit does not distinguish between frequency of sound. In fact, it is really just a noise detector and will hear just about any reasonably loud sound.

Q . I want to detect when my robot's battery goes too low to power the robot. How can I look at the voltage that is running my microcontroller? Won't it be the same as the voltage reference of the analog section of the micro, so I can't detect a low voltage? What if the voltage from the battery is too high for my micro to read without damage?

— Anonymous

A . I hear this question all of the time. The answer is simple: a voltage divider. You can make a simple voltage divider with two resistors. I could try to explain this circuit to you, but it is rather like explaining how to tie shoe laces. So, **Figure 2** shows how to handle a voltage that is higher than the analog input of your microcontroller, as well as de-reference it from your analog reference voltage.

You would probably like to know how this works. Let's assume that you are using a PIC's analog input to measure your voltage. This input is basically limited to the Vcc of your power; let's say 5V. Your battery is a two cell LiPoly battery that can be as high as 8.4V. We have created a voltage divider where both R1 and R2 are the same value, 10K; this means that your voltage measured will be half what the "real" voltage of the battery is. So, if you measure 4.1V on your analog input (if you are using an eight-bit converter) this would be a value of:

$$(4.1/5) * 255 = 209$$

The value is the ratio of your reading divided by your analog reference times your maximum digital value that the analog-to-digital can return. You can play with the resistor divider values to tweak your maximum reading as close to your analog input reference as possible. One thing to remember though is that most analog-to-digital inputs don't like you to have an impedance (resistance) of more than 10K ohms. To the input, the two resistors look like they are in parallel so the effective impedance of this circuit is 5K ohms

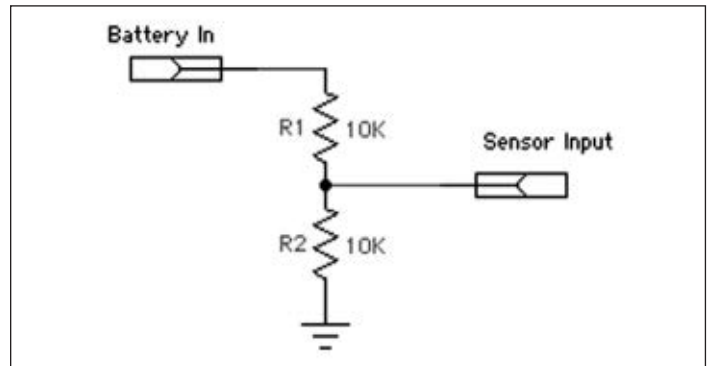


Figure 2. Simple voltage divider.

which is just fine. To calculate the effective impedance of your resistor divider, you would use this formula:

$$R = \frac{1}{\frac{1}{R1} + \frac{1}{R2}}$$

Go forth and conquer!

*There wasn't much in my in box this month, but I did get a question I didn't have time to answer. So, I'll save it for next month as it will take a while to get through. If you have ever wondered how to get your robot to act like it is running several different programs at the same time, stay tuned – all will be revealed next month! As usual, if you have any robotics questions that you would like me to help you figure out, don't hesitate to drop me an email at roboto@servomagazine.com and I'll be happy to work on it! Until next time, keep on building those robots! **SV***

EVENTS

Calendar

ROBOTS.NET

Send updates, new listings, corrections, complaints, and suggestions to: steve@ncc.com or FAX 972-404-0269

Know of any robot competitions I've missed? Is your local school or robot group planning a contest? Send an email to steve@ncc.com and tell me about it. Be sure to include the date and location of your contest. If you have a website with contest info, send along the URL as well, so we can tell everyone else about it.

For last-minute updates and changes, you can always find the most recent version of the Robot Competition FAQ at Robots.net: <http://robots.net/rcfaq.html>

— R. Steven Rainwater

OCTOBER

2 Baltic Robot Sumo

Tallinn, Estonia

Autonomous robots compete in the Sumo ring.
www.balticrobotsumo.org

3-10 Devyanin Mobile Robots Festival

*Moscow State University,
Moscow, Russian Federation*

Autonomous robot race.
www.mobilerobots.msu.ru/en

8 Mindspark

Pune, India

University students compete in engineering events which include robotics and AI challenges.
www.mind-spark.org

9 The Franklin Cup

Philadelphia, PA

Remote controlled vehicles destroy each other for your enjoyment.
www.nerc.us

16 Antimov

SparkFun, Boulder, CO

This competition is autonomous robot performance art in which robots attempt to self-destruct in humorous or entertaining ways.

www.sparkfun.com/commerce/product_info.php?products_id=9975

21-22 Competencia Robotica (LARC)

Valparaiso, Chile

Autonomous robots must search a maze for colored cubes and assemble them into a flag of Chile.

<http://robotica.elo.utfsm.cl/competencia>

22-23 Calgames

San Jose, CA

Students compete in a STEM type robot competition based on the FIRST Breakaway event.

www.wrrf.org

22-24 Critter Crunch

Denver, CO

Autonomous and remote control robots participate in the original robot combat event.

www.milehicon.org

22-24 SRS Robothon

Seattle, WA

This year's Robothon includes Robo-Magellan, Robot Combat, Double-Cross, and Brickheap Wars.

www.robothon.org

23-24 Chibotica

iHobby Expo, Rosemont, IL

Lots of contests including line following, Sumo, table top, and LEGO. Also lots of cool robot demonstrations and displays.

<http://www.chibots.org>

23-24 COMBOTS Cup

San Mateo, CA

Remote controlled vehicles destroy each other for your enjoyment.

<http://combots.net>

27 Homebrew Robotics Club TABLEBot Phase III

Silicon Valley, CA

HBRC is ready for Phase III of their TABLEBot competition in which autonomous robots must navigate on the surface of a table and push an object into a box.

www.hbrobotics.org

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NEW PRODUCTS

ADAPTERS

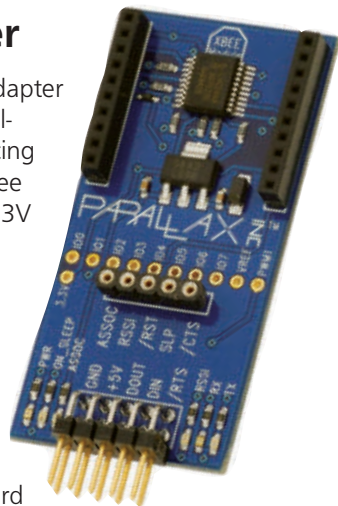
XBee SIP Adapter

Parallax's new XBee SIP adapter is a fully-assembled, small-footprint solution for interfacing the most commonly-used XBee module features with your 3.3V or 5V microcontrollers. With many XBee adapters on the market, Parallax gave this design careful consideration to customize the product for educational and hobby uses. The 2 x 5 dual SIP header makes a sturdy connection to your breadboard or through-hole board, and brings the basic connections to your prototyping area without taking up a lot of space. The more advanced XBee features are still accessible through additional headers on the module.

Features include:

- Onboard 3.3V regulator.
- 5V to 3.3V logic translator buffers common I/O pins.
- Six status indicator LEDs for power, Tx, Rx, RSSI, associate, and mode (Sleep/ON).
- Small footprint dual SIP header provides support and allows easy interfacing to DOUT (TX), DIN (RX), RTS, 5V supply, and ground.
- Five-pin female header connections provide interfacing to other XBee pins such as sleep, reset, and associate.
- A row of 10 plated through-holes with 0.1" spacing allows the option of soldering jumper wires or a header (not included) for access to the remaining XBee pins in advanced applications.
- An additional plated through-hole gives access to a 3.3V output for ADC reference (VREF) when required.
- Adapter board is pre-assembled — no soldering required for using most common XBee features.
- Compatible with all Parallax microcontrollers, including the 5V BASIC Stamp modules and 3.3V Propeller P8X32A.

For further information, please contact:



SERVICES

New IMS Prototyping Service

PCB-POOL® — a leading manufacturer of prototype printed circuit boards — has announced the introduction of a new metal core (insulated metal substrate) PCB prototyping service.

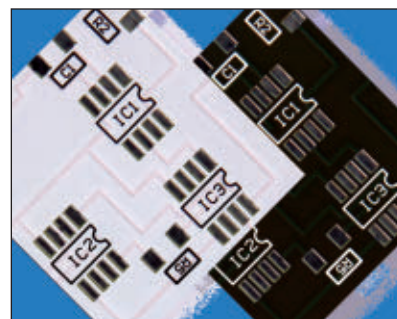
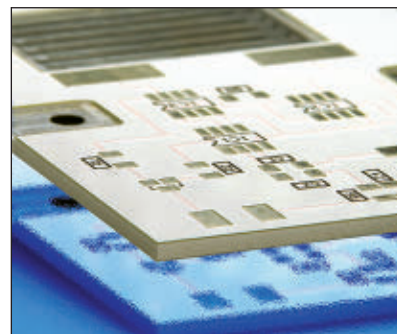
Metal core PCBs are designed to transmit heat away from operating areas on the PCB or components to less critical areas such as metal heat-sink backing and metallic core.

Designers of high intensity LEDs, power converters, automotive applications, or any circuits requiring greater heat dissipation can now take advantage of reduced pricing and shorter lead times offered within this new service. Various machining methods have been integrated in the IMS manufacturing process; these include the ability to produce threaded drill holes, counter-sinking, and controlled depth milling using the latest CNC technology.

Other benefits include:

- One layer IMS PCBs.
- No minimum quantity.
- Various soldermask and silkscreen colors available.
- No tooling or set-up charges.
- Lead free HASL surface finish.
- 1.5 mm thickness.
- 100 μ m isolation layer.
- 35 μ m copper.
- FREE laser SMT stencil with all prototype orders.

For further information, please contact:



Parallax, Inc.

Website: www.parallax.com

PCB-POOL

Tel: 877 • 390 • 8541
Email: sales@pcb-pool.com
Website: www.pcb-pool.com

SERVOS

New ISS Intelligent Servo System

Acuity Technologies, Inc., introduces its ISS line of intelligent servos. The servos are designed as compact sealed actuators for autonomous and remotely controlled vehicles in aerospace, surface, marine, and industrial robotic applications.

Available in industrial and extreme environment grades, the line of servos is capable of 1 to 12 Nm of torque and speeds from 15 to 500 rpm. They can be controlled via CANBus, serial lines, pulse-width or analog signals, and will accept 12 to 48 volts power. A single power/signal cable simplifies installation. The wide speed and power range makes them suitable for control surface actuators, retractable landing gear, drive motors for wheeled or tracked vehicles, and robotic arms.

"These servos fill a need for power and reliability above the high-end R/C servos where virtually no standard products have previously been available," commented Robert Clark, Acuity's president. "We started out looking for servos for a Navy UAS but had to build them due to the lack of selection in speed, power, and form factor." For

those requiring high reliability, configurable status/error reporting allows monitoring of servo status and bus integrity. The servos may be operated in position, velocity, or torque mode with update rates of up to 1,000 per second for high performance autopilot or human control. The network servo controller provides a single serial interface and power distribution for a network of up to 32 servos in a star/daisy chain topology. For further information, please contact:

Acuity Technologies, Inc.

3475 Edison Way Bldg P
Menlo Park, CA 94025
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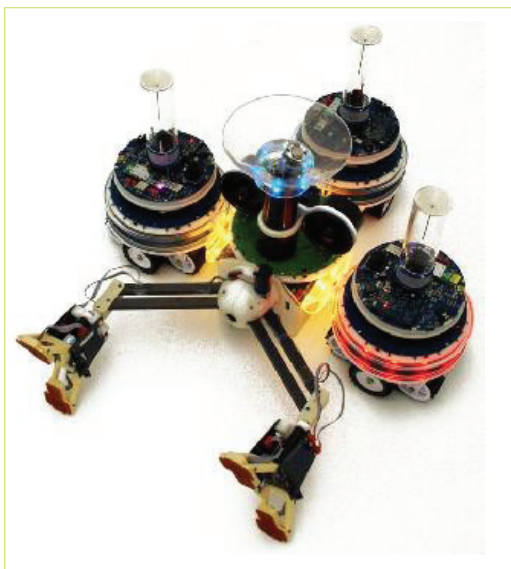
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bots IN BRIEF



MANIPULATIVE ROBOT

The reason that this is called Handbot is that it's designed to be the manipulation portion of a robot made up of individual specialized sub-robots, including Eyebots for sensing and Footbots for ground movement. The whole shebang forms "an heterogeneous robotic system" called Swarmanoid, and eventually, one Swarmanoid assemblage will be comprised of some 60 individual Handbots, Eyebots, and Footbots capable of cooperatively moving around, sensing, and manipulating in 3D space.



PYRAMID SCHEME

Even though it's been some 4,500 years, there's still a little bit of the Great Pyramid that's entirely unexplored. From two chambers inside the pyramid (the King's Chamber and Queen's Chamber), there are small shafts (about the size of a breadbox) leading away towards the exterior. These passages are blocked by stone doors with copper handles built into them, and a previous expedition found that behind was of the doors was ... another door. So this time, a team sponsored by Leeds University and supported by Dassault Systems has built a robot designed to find out what's behind that next door. It's totally tricked out, with:

- A micro "snake camera" that can fit through small spaces and see around corners like an endoscope.
- A miniaturized ultrasonic device that can tap on walls and listen to the response to help determine the thickness and condition of the stone.
- A miniature 'beetle' robot that can fit through a 20 mm diameter hole for further exploration in confined spaces.
- Precision compass and inclinometer to measure the orientation of the shafts.
- A coring drill that can penetrate the second blocking stone (if necessary and feasible) while removing the minimum amount of material necessary.

This is actually the third robot that's been sent down this particular shaft; the second was an iRobot project in cooperation with National Geographic.

In 1992, a robot was sent into one of the Great Pyramid of Khufu's shafts to explore its contents. Upnaut 2 found the limestone doors with brass handles. National Geographic sent in a drilling bot sometime later and discovered the second door. Now Leeds University's Dr. Robert Richardson has planned this third excursion that will probably take about five years to complete. The hope is the drillbot — equipped with a camera — will discover lost secrets in the Queen's chamber.



The Djedi Team, from left to right: Stephen Rhodes, Robert Richardson, Zahi Hawass, Shaun Whitehead, Adrian Hildred, David Keeling, Ron Grieve, Jeff Vale, TC Ng.

(Photo by Meghan Strong.)



bots IN BRIEF

READY TO ROLL

NASA's Mars Science Laboratory Project will launch Curiosity in late 2011 for arrival at Mars in August 2012. The mission will study whether an intriguing area of Mars has offered environmental conditions favorable for supporting microbial life and for preserving evidence of whether life existed there.

On Mars, of course, Curiosity will not need an umbilical cord. It will communicate by radio, and it will be powered by a radioisotope thermoelectric generator — essentially a nuclear battery that reliably converts heat to electricity — to be installed just before launch.



A test operator in clean-room garb holds umbilical cables for NASA's Mars rover Curiosity during the rover's first drive test back on July 23, 2010.

*Technicians and engineers conducted the drive test in the Spacecraft Assembly Facility at NASA's Jet Propulsion Laboratory in Pasadena, CA.
Image Credit: NASA/JPL-Caltech.*



GROWS ON YOU

Meet Plant. (Yep, that's what it's called.)

Each of Plant's 169 artificial leaves are controlled by a piece of shape memory wire. When cameras mounted above Plant see your hand move over it, it signals Plant to shimmy its leaves in the same area in response to a 'virtual wind.'

Plant was designed by Akira Nakayasu, and will be on display at Ars Electronica 2010.



Photo of Plant sans leaves.

Cool tidbits herein provided by Evan Ackerman at www.botjunkie.com, www.robotsnob.com, www.plasticpals.com, and other places.



HERE'S THE SCOOP

Meet Yaskawa-kun — Japan's newest robot. He has two special skills: He looks cute, and he can make and sell ice cream. Recently, he worked at Tokyo Summerland, a big theme park, peddling cones.

The way you order is pretty simple: Step up to the ice cream stand and select what you want via a touch screen (it's possible to choose the size, sauce, topping, and other things). Confirm with another push of a button, pay, and watch Yaskawa-kun make the ice cream and hand it over to you.

Yaskawa-kun is the brain child of Japanese robot maker Yaskawa — a major Japanese bank and a leading advertising agency. The three

companies want to continue conducting experiments with the robot and hope to lease or sell future versions.



HERE'S THE SCOOPER

WowWee is continuing to release inexpensive robot toys, however, the new Roboscooper actually might have a practical application. If you want things that weigh about an ounce lifted up and carted around. Here's what Roboscooper can do:

- * Scoops objects up automatically when in autonomous mode, or when controlled by the included remote.
- * Nimble. Has six wheels allowing it easy traversal over most terrain.
- * Multi-directional mobility.
- * Funny phrases and sound effects.
- * Sensors in his hands allow it to detect objects in front of it on the floor and pick them up, or knock them around.
- * Obstacle avoidance.



This is the robot that picks up objects at your command and loads them onto its cargo bed, emptying contents at your preferred location. The remote drives the robot left, right, forward, and backward — with skidding sounds for stops and beeps when in reverse, allowing you to nudge it into place for picking up small items such as balls, toys, or socks with its two articulated arms and hands. It can also operate

autonomously using its four infrared "eyes" that seek and detect objects within its 8"-12" sight range while it announces "Let's get to work!"

Once an object is secured, the robot's torso pivots to deposit an object into its cargo bay; it dumps contents by vibrating to dislodge objects from the bay, adding "one step closer to a cleaner world." Completely aware of its environment, it informs you when an object is either too large or fixed with "too heavy for me" and "uh ... a little help, please" if it gets stuck. It can also issue beefy, two-handed slaps to objects when set into "whack" mode, urging you to "let 'er rip!" when ready.

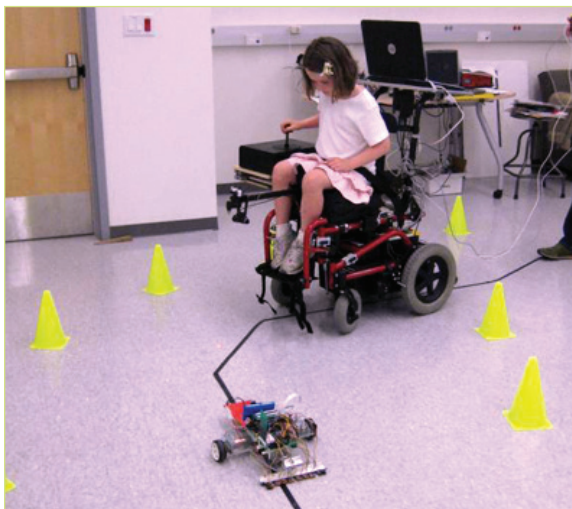
Roboscooper will run you about \$70.

CREEPY CONTACT

There must be a fundamental perceptual difference when it comes to robots in Japan (as opposed to robots from the rest of the world), because there seems to be a tendency there to totally ignore the whole Uncanny Valley issue so many of us get hung up on. Take Telenoid R1, for example.

The idea behind the design of Telenoid R1 makes a lot of sense. The robot is intended for remote telepresence and communication, and as such, it's supposed to distill a human form into just the essential communicative elements. So, you've got a face that's intended to be featureless and asexual, stumpy little arm things, and a soft torso with no legs. But really?

Telenoid R1 comes from Hiroshi Ishiguro (who you probably remember for his not quite as creepy Geminoid F). Inside, it's got nine actuators that will mimic the arm, face, and head motions of the user who's communicating through the robot (via a motion-capture webcam). We're not sure, though, that the Telenoid R1 will actually enable users to "feel as if an acquaintance in the distance is next to you" as the developers assert. In any case, it is going on sale, and you can expect to pay \$34K for the research version, and \$8K for a general-purpose version.

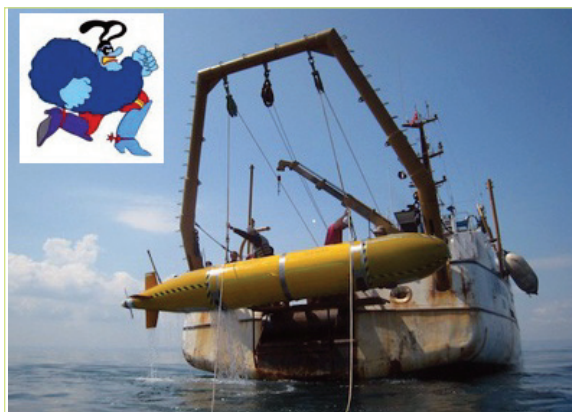


WAY TO ROLL

Training younger children to use a wheelchair can be difficult and requires a therapist to take them step by step. Dr. Laura Marchal-Crespo and a team at the University of California at Irvine have developed ROLY (RObot-assisted Learning for Young drivers) so that no assistance is required and the kids can learn at their own pace. The chair uses haptic guidance to follow a line on the floor using computer vision while the child determines how much control of the joystick is needed.

RIVER RUNNER

The University of Leeds has recruited a robotic submarine to explore a river under the sea. Apparently the body of water is large enough to be the sixth largest river on (under) the planet. The 23 foot long yellow sub carries a camera to explore what life may be hidden in the depths.





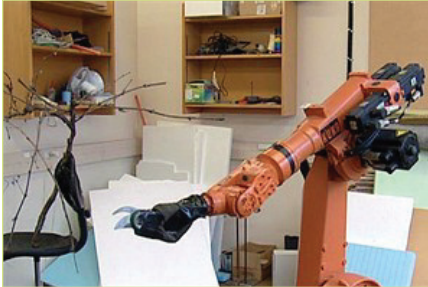
DESK ADORNMENTS

It's a calculator, message poster, and pencil holder, but mostly it is a helpful robot that can hang out on your desk. Available in green, blue, or white, this assistant will make a fine companion for your Holmes robot desk lamp. It comes complete with adjustable head, body, arms, and legs, and clip-on hands for holding what the calculator cannot. It's available on **Amazon.com**.

THIRD TIME A CHARM?

Aimec 3 (Artificially Intelligent Mechanical Electronic Companion 3) is a four ft tall service bot dreamed up by Tony and Judie Ellis of East Sussex, UK. With a camera for finding its way around, the third gen prototype understands verbal instructions and can perform chores such as dimming lights, turning on the TV, and even accessing the Net to read the news. He can also sing, tell jokes, and do impressions.

The couple is hoping to find a manufacturer and believes that Aimec will be the real deal in a couple of years at a price of £200 (~\$311). Ellis certainly knows what he is doing as he is the creator of the highly successful Cube World.



GRAPE IDEA

New Zealand may soon have new helpers in its wineries. Canterbury University's Dr. Richard Green is working on a robot that can prune vines using 3D cameras to gauge distance. The target date for a working model is two years. The bot can be adapted for other industries, but for now they see it as saving \$20 million a year in that country.

WALL-EYE

Two years after the release of the movie "Wall-E", Disney continues to allow licensed products to keep it alive. This is Eve USB 2.0 Hub with four ports and she is both Mac and PC compatible. At a size of 2-1/4 x 2-1/8 x 3-1/4," she has adjustable arms, rubberized wheels, and her eyes light up when connected.

Find her at **Amazon.com**.



THAT SINKING FEELING

Thanks to NASA's ASTEP funding, an underwater robot is studying biology in a series of sinkholes in Zacatón in northeastern Mexico. So far, the autonomous DEPTHX — guided by a team of several universities — has gathered 100 types of microbes, in almost 50 dives, including three new phyla of bacteria. It will continue to seek the unknown in months to come.

DEPTHX dove about 900 feet (275 m) deep towards the bottom of the Zacatón sinkhole. The craft retrieved samples of water and microbes lining the limestone sinkhole.

The scientists also used data gathered by the robot's 54 onboard sonars to create high resolution, three-dimensional maps of the underground hole which had never before been explored to such depths.

Sinkholes are depressions in the ground that are thought to be formed by the chemical dissolution of carbonate rocks, leaving behind a void that can fill up with water or air.

The Zacatón sinkhole is about 344 feet (105 m) across and is filled with water that stays about 86 degrees Fahrenheit (30 degrees Celsius) throughout the year. The water contains sulfuric compounds that serve as a food source for some of the life within.



*Scientists lower the DEPTHX robot into the water in the Mexican Zacatón sinkhole. A researcher floats nearby in a kayak.
John Spear / Colorado School of Mines.*



GREAT ESCAPE

Elenco's latest kit creates an Escape Robot that can process information and maneuver around objects autonomously. The kit has a microprocessor, three infrared emitting modules, and an IR receiving module. Two different sets of legs can be used for different types of movement. Some soldering is required.

TOP SHOP

The Liberty Street Robot Supply & Repair, located in Ann Arbor, MI, not only fixes your broken bot, they sell upgrades, attachments, kits, and add-ons. They also staged a recent Robot Fair during that city's Art Fair in July. Best of all, their proceeds go to the free student programs at 826michigan.org which is a non-profit tutoring and writing center.



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Zergling

● by Kyle Singer

Back in February, I decided that I was going to build drums for the PA Bot Blast, Horizontals for Franklin, and VDs for Moto. Well, the Bot Blast has already come and gone, so now it's time to get ready for Franklin. I was planning on taking two ants and a beetle; I already have one horizontal, Szalor, so I thought I would try my hands at an undercutter. I started the design process ...

First, I chose a weapon disc out of my toy box. For any design, it's important to know the size, weight, and placement of your weapon in order to build a successful bot. I had my design, so it was time to start building (**Figure 1**). I started by laying out the top and bottom plates with 1/32" thick and 1/16" garolite, then cut them out. For the 1/32" piece, I simply used tin snips. As for the 1/16" thick piece, I set it up

on the mill; this creates a nice straight cut and a clean finish (**Figure 2**). For clamping down

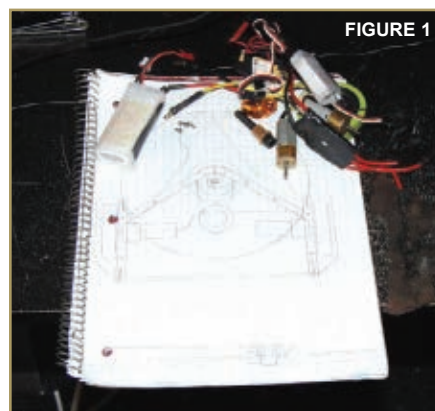


FIGURE 1

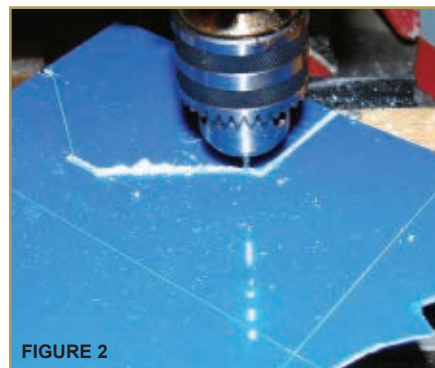


FIGURE 2



FIGURE 3

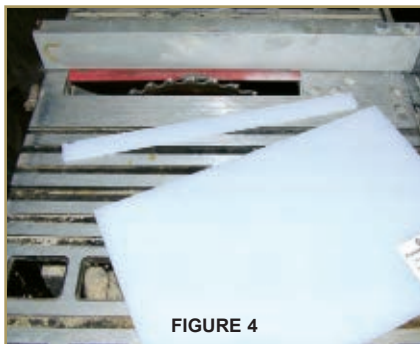


FIGURE 4

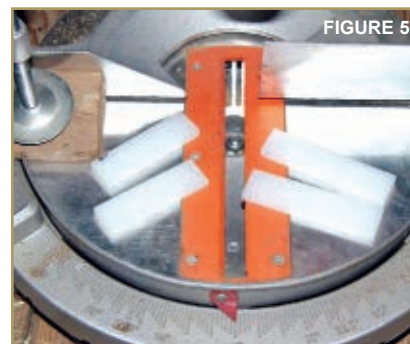


FIGURE 5

the 1/16" piece, I've found the best method is to bolt down a board, then use wood screws to clamp down the piece.

I proceeded to drill out holes for frame rails and for the brushless motor mount (**Figure 3**). Because the front of the robot is going to be receiving the most amount of abuse, I decided that four bolts per each frame rail would be significant support. I also drilled a large 1-1/8" hole in the top of the 1/32" plate for the brushless motor.

Now that the base plates were finished, my next step was to cut out some frame rails. I planned to make the entire frame of the robot 3/4" high, so all I had to do was set up the table saw and rip a piece of 1/4" UHMW (**Figure 4**). I then took that piece to my cut-off saw and cut two 2-1/2" long pieces and two 3-1/4" long pieces (**Figure 5**).

With the pieces the proper length, I needed to create the proper angles for the front pieces. In order to do this, I again set up the mill, I measured the angles, clamped the pieces in, and ran a 3/8" end mill over the end (**Figure 6**). The last major step before I drilled out the rails and mounted them was to create slots to mount the motors. I set up the mill again and proceeded to mill a 3/4" slot 1/8" deep into the UHMW.

I marked everything out and used a center to create a pilot. I then drilled out all the mount holes to 7/64" to later be tapped out for a 6-32 machine screw. I

also drilled out the holes to mount the drive motors (**Figure 7**). I then went back and ripped out a 1/8" piece of poly and drilled it out. Things were really starting to come together (**Figure 8**), but there was one setback. I put everything on the scale and it was over weight. So, I had to change a few things about the design.

First thing I changed was the disc; as it turned out, I had some lighter discs of the same size. It also turned out I had some wheels of the same size that were also lighter, so I switched them out, as well. Since the robot was still a little over



FIGURE 6



FIGURE 7

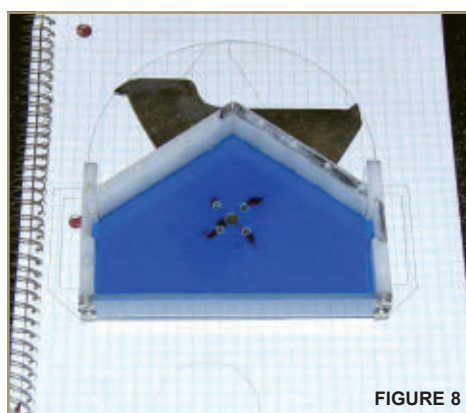


FIGURE 8



FIGURE 10

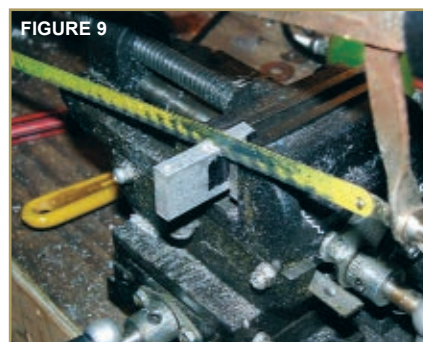


FIGURE 9

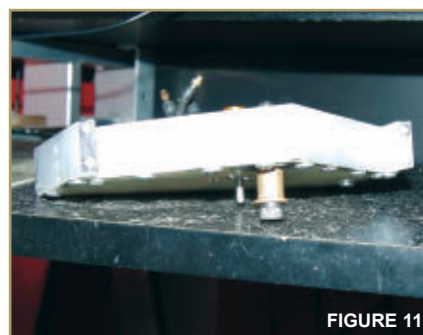


FIGURE 11

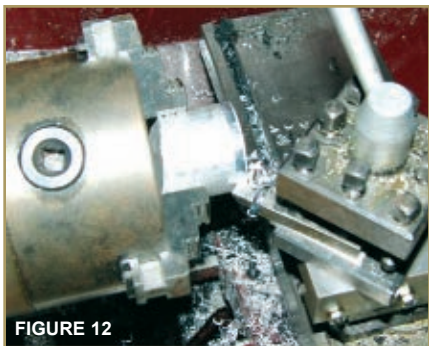


FIGURE 12

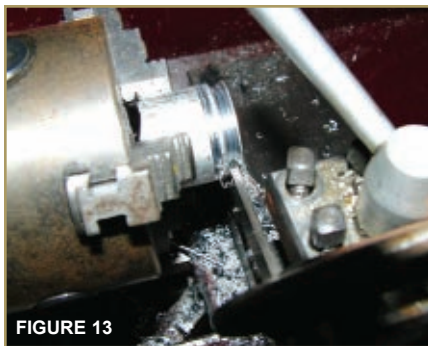


FIGURE 13

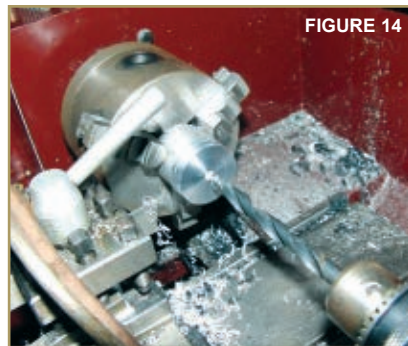


FIGURE 14

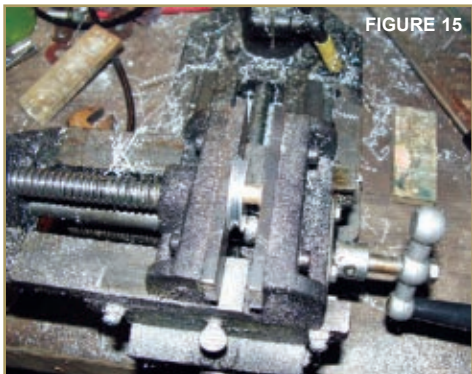


FIGURE 15

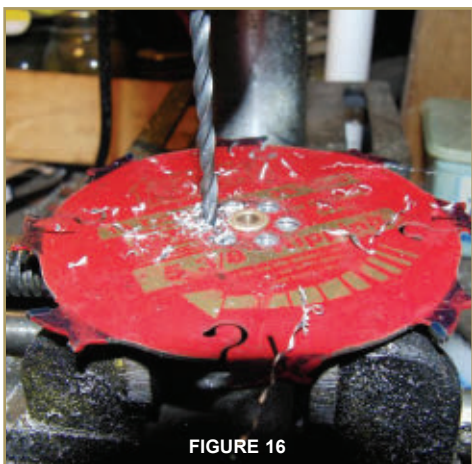


FIGURE 16

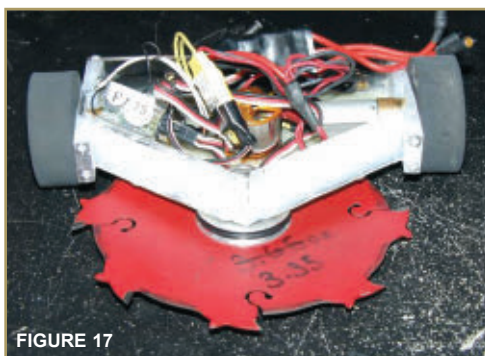


FIGURE 17



FIGURE 18



FIGURE 19

weight, I was forced to the last resort of replacing the 1/16" thick base plate with a 1/32" one.

After completely remaking the bottom plate, I started on the weapon assembly. For this, I needed a nice sturdy piece of aluminum, so I cut off a 3/8" thick 1" wide chunk with a hack saw (Figure 9). I had my piece marked out and began milling the angles so it would fit into the nose of the bot.

After milling the general

shape, I set it up in the drill press and drilled three 7/64" holes to bolt it to the plate. I also drilled one 13/64" hole which I would later tap out to 1/4-20 for an alloy steel bolt that would later be the weapon shaft (Figure 10).

At this point, I bolted everything together and mounted the weapon motor; it's ready for a weapon (Figure 11). The last major part for me to make was a pulley to bolt the disc to. I have a maximum OD clearance of 1-3/4" and a minimum 1-1/8" ID clearance, so I went with the minimum to keep the ratio as high as possible. I loaded a piece of round stock into my lathe and began work by putting a 1/4" wide 90 degree groove at a 45 degree angle (Figure 12). I then went in with the parting tool and created a 1/16" deep cut in the center on the groove (Figure 13). To

finish off the lathe work on the piece, I drilled a 3/8" hole through the center for the bushing, then used the parting tool to cut it off from the stock (**Figure 14**).

Next, I simply pressed in the bushing using the vise on my drill press; this created a nice tight fit that with any luck will never come out (**Figure 15**). I was down to the last stages of this piece and the

robot, so I grabbed my disc, set it up on the piece, marked it out, and began drilling three 13/64" holes which I later tapped out to 1/4-20 (**Figure 16**). The disc had room for six 1/4-20 bolts but three is more than enough for an antweight.

I was now ready to assemble the robot, cram everything in, wire it ... it's ready to fight (**Figure 17**). I originally intended for there to be

wheel guards on the bot — that's why the side frame rails extend in the front — but being pressed for weight leads to sacrifices in the design.

Figure 18 shows the finished product.

As with all my robots, inverted operation is a must; it's senseless to lose a match over something as simple as being flipped (**Figure 19**). **SV**

MANUFACTURING: Composites – Part 2

● by Bradley Hansted

In this month's article, I will cover a very basic lay-up process, the tools you need, and the safety precautions to take. I will be diving right into the steps one may take to make a simple two ply carbon fiber panel. I highly recommend reading my first article from Sept. if you are new to composite structures as you will learn information that will carry over into these steps. Some terms and abbreviations will be used in this article that you may not know. To decipher these terms and learn where to ask more questions, head over to: www.teamthinktank.net/composites.

Before going to cut up a bunch of carbon fiber to make a panel, you first need a surface in which to cure your part. Planning ahead is key to fabrication as you may be in gloves with resin on them and forget to get something out. Always walk through the process in your head to make sure every step is covered. So, before you cut up your cloth and get out the resin, choose what shape and what surface this part will be made on. For this simple flat panel, we will use a flat 1/4" thick aluminum plate that at least has 2" of extra material on every side to

whatever sized composite part you wish to make. Aluminum is great because you can transfer heat to the part which will aid in curing and it can be polished easily for a great looking part. Whatever the surface of the mold plate looks like is exactly what you will get in your finished part. So, sand or prep that plate to your desired finish.

Now that we have a mold, it's time to get your cloth ready. Cut the bi-directional carbon fiber cloth to slightly larger than the desired size plate you wish to make. The reason

to have excess on the ends is because it is almost impossible to ensure the ends of the fabric are perfectly aligned and not frayed by the time they are impregnated with resin and cured. No matter what part you make you will always have a small lip around the part to cut off later. Cutting the carbon fiber can be a bit tricky, but it is nowhere near as hard to cut as kevlar, so just get out some strong fabric shears and get those pieces cut to size.

The next step will be to place the carbon sheets on top of each

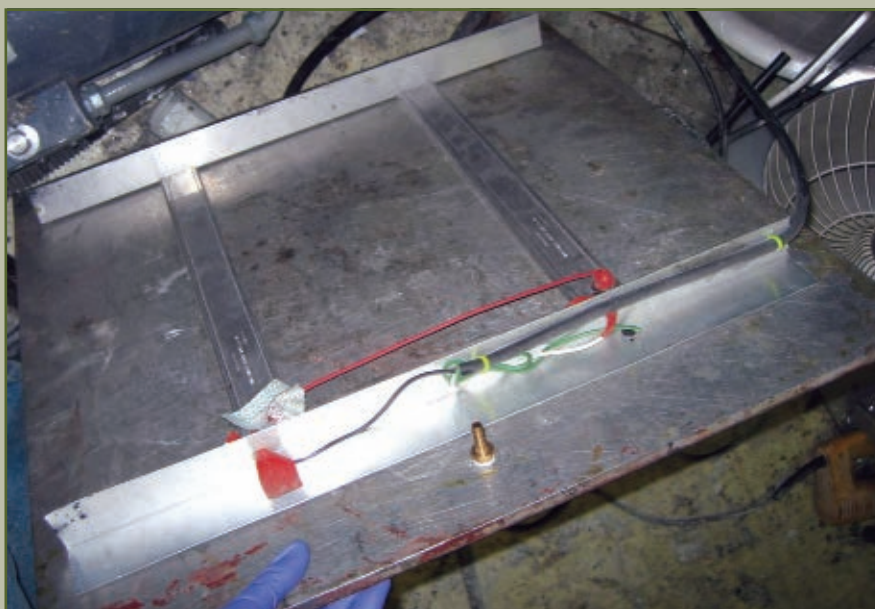


PHOTO 1. TTT's aluminum mold plate with two heating bands and hose connection barb for easy vacuum bagging.



PHOTO 2. A few of the safety and general supplies you will need.

other and align it on the mold. Remember the position in your head (or mark it) and pull the fabric off the plate as it is time to add a release. A release agent will allow the molded part to come off the aluminum plate when the part is done curing. Choosing the right release is also key to how the molded part may perform.

Traditionally, wax is the cheapest and most readily available release agent, and it can work quite well if applied correctly. Just remember if you use this system to apply criss-cross, not "Karate Kid" circles, yet wax on and wax off with

that criss-cross pattern. Apply at least 3-4 coats for the first time using the aluminum and always make sure the mold surface is cleaned well beforehand with some Acetone. Dish soap is a nasty thing in the composite world as it will leave behind agents that could possibly corrupt your resin matrix.

Team Think Tank (TTT), on the other hand, uses polyvinyl alcohol (PVA) as their mold release of choice. There are a ton of releases out there, however PVA has stood out as the best. It can be applied through an air gun, or simply by paint brush. It will create a thin film that is water-soluble which means

you hit it with water and it will dissolve. Unlike other releases that may stick to the part and make secondary processes a pain, you can take the part to the sink and rinse it all off. You would apply this release on the mold but leave at least a 2" border not covered in it if you go the vacuum bagging method used in this article.

Resin time? Not quite. We need a few more materials — especially if we are vacuum bagging. We now need a piece of peel-ply to go on top of the panel. Peel-ply can be made from various things, but the cheapest to get your hands on would be some nylon fabric with the most open weave you can find. This material is placed directly on the part so that when it cures, it will have small grooves on its face to allow for gluing to secondary parts or layers.

Also, get your hands on a trash bag or perhaps a ziplock bag that you can tape to your workbench next to the mold which will give you a place to first wet-out the carbon fiber sheets before applying them to the mold. If you desire a mirror finish on both sides with a wet layup, then go ahead and acquire a secondary aluminum plate treated with release and use that to sandwich the carbon.

If you desire to vacuum bag instead, then please go over the extra materials you will need to prepare. This will include a plastic perforated layer cut to size, cotton batting (to be used to soak up extra resin) cut to size with an extra piece to cover the vacuum outlet, and a cut-up trash bag layer to cover the entire thing out to the 2" border with duct tape to tape it down and seal it air tight. Besides these extra layers of materials, the most expensive item will be the vacuum pump itself. You can rig up a shop vac to



PHOTO 3. Vacuum bagging materials already in order waiting for us to grab them.

attempt to vacuum a part, but I highly recommend spending a little cash and at least buy a used vacuum pump. These are made for running a long duration under suction force. Also be sure to pick up a vacuum bagging inlet which makes it much easier to bag and tag parts. However, you can just run a tube directly under the trash bag, but it may be a challenge to seal properly.

It's time to get out one of your most prized possessions: your scale! Weigh your fabric and calculate out an approximate 66:33 ratio of cloth to resin. This will be enough resin to wet-out for the process, but you may need almost a 50:50 ratio for vacuum bagging as you will get some resin sucked into the bleeder material (cotton batting).

You will have to experiment a bit to have the right amount of resin to just impregnate the cloth fully, but you never want excess resin as it will create a weak, brittle spot in your part. Write down the weights before and after the part is cured to figure out what ratio your finished part has. The less resin in a properly impregnated part, the more it will rely on the strength of the cloth itself which is what we want in combat robots.

In a structural part, I would shoot for a Max Bond resin, but if you need visual clarity purchase a Max CLR kit as mentioned in the previous article. Weigh out the correct amount of A and B (resin and hardener) in two separate plastic cups (make sure the cups are not styrene so you can always add Acetone to clean them out or to thin out resin). Have a third cup ready to pour A and B into, and never cross contaminate these two cups. That way, you can always use these two cups for weighing out the resin in the future without waste. Also have a few tongue depressors out which will be used as stir sticks and scrapers to scrap the resin out of the cups, as well as a plastic spatula for spreading the resin out on the cloth.

Before we go ahead and mix that resin together, let's go over some safety precautions. (I am not liable for your misuse of these materials, but I want you to be safe.) Get a respirator or a good surgical mask to prevent inhalation of any chemicals or stray fibers, and always operate in a well ventilated room. Get lots of nitrile gloves now, as you will use them! Never touch chemicals with your bare hands if you can help it. Safety goggles are a big plus as well; splashing resin in your eye sounds like some bad juju. You can get resin off of things with Acetone since according to the government it is not a hazardous material, but do not inhale or get over-exposed to Acetone if you can help it. Now that we have some safety rules established, let's make a part.

Get all your materials ready and all the different layers of materials you will be placing on the mold in order (this is called the schedule). Safety up, glove up, and pour A and B into the third cup; use a separate tongue depressor for each cup to scrape out every last bit you can. Mix really well, scraping the sides and bottom often. It is generally recommended to transfer the mixture between at least two cups

to create a proper mixture, so do this if you want to insure a proper resin matrix.

With the resin mixed in the cup, you now have a hot pot; the longer it stays in the cup in one mass, the quicker it will kick-off and cure on you. Luckily, you went with my suggestion for resin, right? If not, read the MSDS and information on the resin to figure out the working time. With Max Bond, we have plenty of time to work with the resin before it gels (B stage).

Now it's time to get that fabric ready to be impregnated. Take your first sheet of carbon fiber and place it on the plastic sheet we set up earlier. Pour the resin from the mixing cup onto the sheet in a fine stream (this will insure less air bubbles getting into the laminate) and spread out the resin using a plastic spatula. You should use half the resin and get the entire piece soaked. If it isn't all the way wet, add some pressure and use a 45 degree angle on the spatula to make sure you spread the resin well.

In the worst case scenario, use more resin and be prepared to weigh out a little extra once you run out on the next sheet. Once the first piece of carbon fiber is wet-out, place that in the middle of the mold



PHOTO 4. Heat lamps can work great, but never leave them unattended. Notice the large burn spot ... oops.



PHOTO 5. After reading this article, you just created a VD6! Not quite, but these fundamental techniques can take you slowly but surely to a level of expertise so you can create such a monster.

and repeat the process.

Now that you have the pieces of fabric on top of each other, you are just about done. Apply the layer of peel-ply to complete the wet layup process. However, if you seek the better method of vacuum bagging, add your perforated plastic film, cotton batting, and get that trash bag ready. Figure out how you will have the vacuum line go inside the trash bag layer, and place the extra piece of cotton batting over that line. This insures any extra resin that makes it past the standard cotton batting won't go into your vacuum line and gum up the works of your pump; also make sure that the hose isn't sucked to the table and has some space to suck up all the air.

With all of that positioned, carefully duct tape all sides of the trash bag to the mold in the border that isn't covered with release, and make sure you don't allow creases

to form in the tape. The better that tape is laid, the better chance of not having air leaks. Proper sealing can be one of the toughest parts of the vacuum bagging process.

Now with your part happily working its way to cure, there are a few things to consider. If you need your part to cure a bit more rapidly, you can apply heat through various ways (lamp, heat gun, car on a hot day!) to force the resin to kick off rapidly. The aluminium molding plate will allow you to get heat directly on the part, as well. For the absolute best cure, allow the resin system to hit the C stage, or initial cure. Then post cure it with heat at about 240 degrees Fahrenheit for 1-2 hours (make sure all materials being used can withstand the heat, including your release). This will create a very strong part. However you approached it, it is time to sit back and allow the part to fully cure under vacuum pressure.

Once cured, it's time to check out your part. Remove the plastic and other excess materials. In most cases of flat molding, the part will come right off without even needing to melt the PVA with water. If for some reason you do need help in getting the part free from the mold, remember to never use metal tools! Always use wood or plastic wedges to wedge under the corners and work around the mold to get it free. This prevents damaging the part or the mold.

Now that you have your part, you will want to carefully cut off the excess fray. The single carbon threads that can be resin impregnated can turn into needles. From extensive experience, I can tell you carbon splinters hurt like hell.

Cutting is best done with a band saw using a gulleted blade, but with such a thin laminate you should be able to cut with shears or any blade.

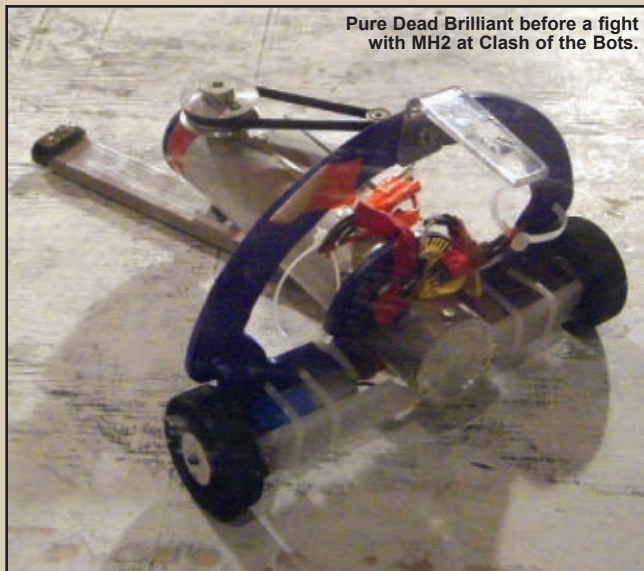
With a new shiny part in hand, you may want to go farther. As far as secondary processes, shaping, mold making (tooling), attachment to metal substrates, etc., I simply cannot cover that much material in this article. If you would like more information, I would be happy to continue writing articles for *SERVO Magazine* that cover these specifics and tips that you can only learn with experience, but I need your questions and feedback to target the information. Feel free to contact me at Teamthinktank@gmail.com as I am always available for comment. Check future *SERVO Magazines* for more articles from TTT! **SV**

COMBAT ZONE'S GREATEST HITS

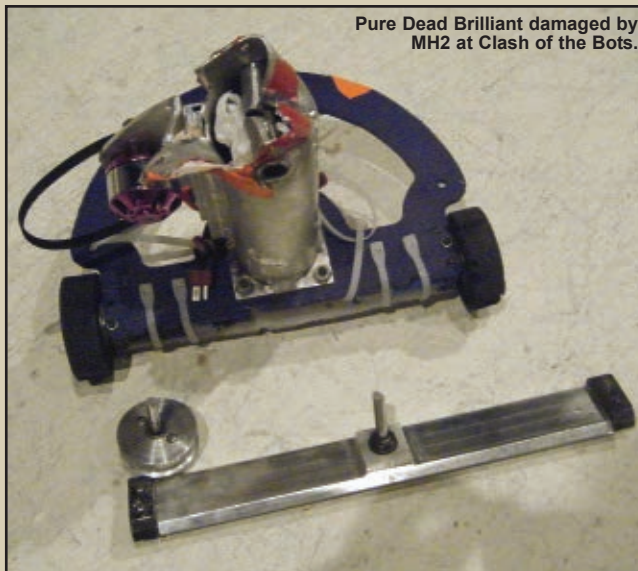
● by Kevin Berry

Pete Smith, of KitBots fame, sent in this one from the recent "Clash of the Bots" event. Pure Dead Brilliant,

whose blade was featured in the August '10 edition of *Combat Zone*, took a bit of a beating at the "hands" of MH2. **SV**



Pure Dead Brilliant before a fight with MH2 at Clash of the Bots.



Pure Dead Brilliant damaged by MH2 at Clash of the Bots.

Before and after photos, brief description of the fight, and builder's name can be submitted to me at LegendaryRobotics@gmail.com. Or, if you have an action shot that clearly shows what's going on, those are welcome too! These don't have to be current, anything you can (legally) submit, clear back to the Good Old Days of wooden bots and iron builders, is fair game.

PARTS IS PARTS: O-Ring Wheels for Ants

● by Pete Smith

Antweight (<1lb) combat robots use a variety of different drive motors and finding small, light, and robust wheels for them can

be a problem.

In this article, I will show you how to quickly make wheels to fit any shaft and to any diameter

you need.

The wheel consists of an aluminum disk with a groove to fit a rubber O-ring (to give the wheel

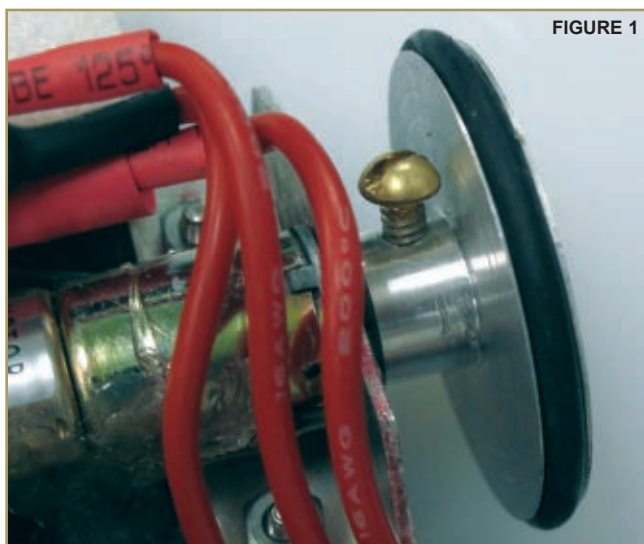


FIGURE 1



FIGURE 2

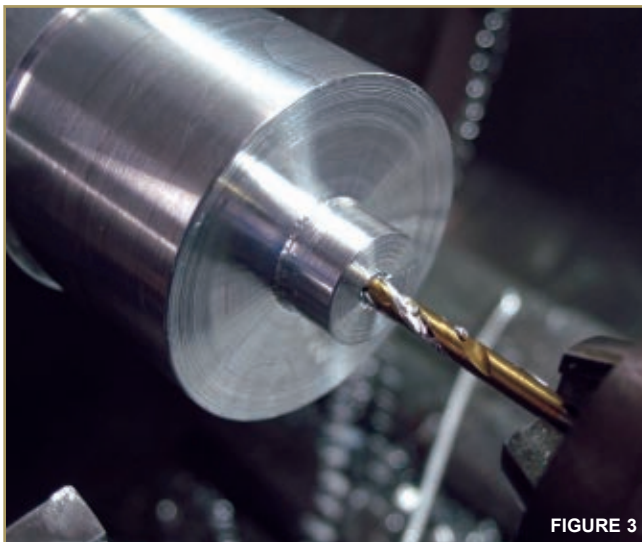


FIGURE 3

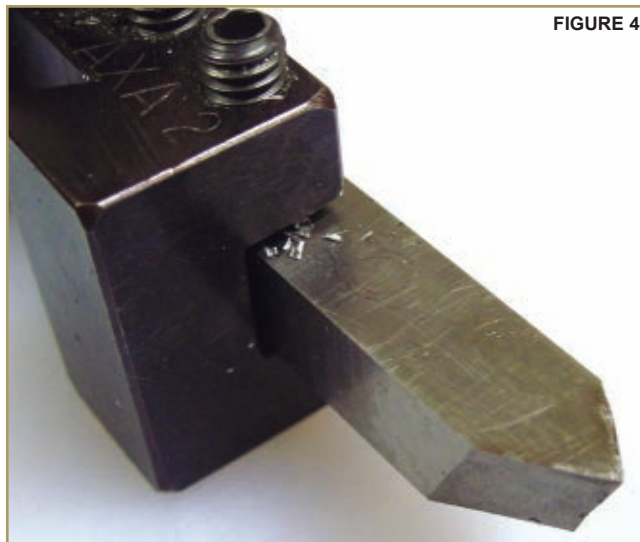


FIGURE 4

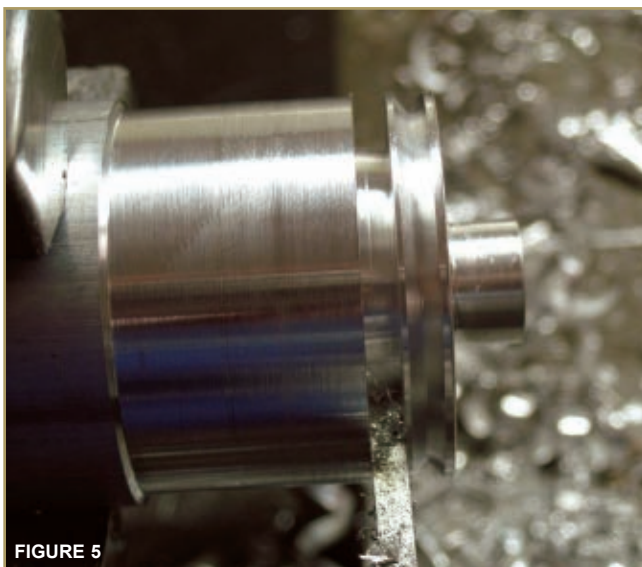


FIGURE 5



FIGURE 6

some grip) and an integral hub. The hub is drilled to the correct size for the shaft required, and cross drilled and tapped to allow a screw to secure the wheel (**Figure 1**).

Start with a 6061 Al round bar that is the diameter — or slightly larger — of the required wheel. The chosen diameter of the O-ring should be subtracted from the final overall diameter of the wheel to get the required diameter of the bar. If you use 1/8" rings for example, a wheel with



FIGURE 7

a finished diameter of one inch, will need the bar turned down to 7/8".

Safety Note: Machine tools are not toys and can injure or kill. Do not wear loose clothing, necklaces and rings, and wear safety glasses at all times.

The bar is faced and then turned down to the required diameter in the lathe (**Figure 2**). Turn down the hub (I make my hubs 1/2" in diameter and 0.3" wide) and drill for the correct shaft size (**Figure 3**). I like to start with a slightly undersized drill bit as I want the bore to be a

neat fit on the motor's shaft; drills often go oversize. You can always make the bore bigger but it's tough to make it smaller!

Next, I use a Style E 60° thread tool bit (**Figure 4**) to make a 0.080" deep groove, 0.090 in from the edge of the wheel. This will act as the retaining groove for the O-ring.

The part is cut off with the "rim" of the wheel 0.180" wide

(**Figure 5**). Repeat the steps above for the number of wheels you require.

Place each wheel in turn in the chuck and counter bore the wheel about half its thickness (**Figure 6**). This step is not required but will save weight at very little loss of strength.

I use a drill press to cross drill the hub and then tap 8-32 all the way through (**Figure 7**). You could

reduce the size of the hub and use a smaller 6-32 or 4-40 set screw, but I find the bigger size less prone to breaking the tap and the screws easier to handle.

Finally, take your wheel up to your local "Ace Hardware" and find an O-ring to fit. If they do not have the correct size to make a nice tight fit, then you can source them from suppliers like **www.mcmasters.com**. **SV**

Life Cycle of a Fighting Robot

● by Mike Jeffries

Apollyon started as a concept for a simple but somewhat unique 12 lb wedge bot. The original design started as a sketch in a notebook during class. Later, it moved into 3D in the CAD program Rhinoceros. I used Rhinoceros as a three dimensional sketching tool, playing with drive systems and the details of the shape.

After this model was completed, I moved the design into Solidworks. This allowed me to finalize the dimensions and prepare drawings for the complicated portions of the design.

At this point, the parts for the robot were ready to be ordered. Most of the components came from **RobotMarketplace.com** and the custom machining was done by **teamwhyachi.com**.

Parts trickled in over several weeks and the robot began to take shape.

At this point, the build was far enough along to begin planning for its debut. During this time, more work occurred and the exterior structure of the robot was completed.

There was still a lot of

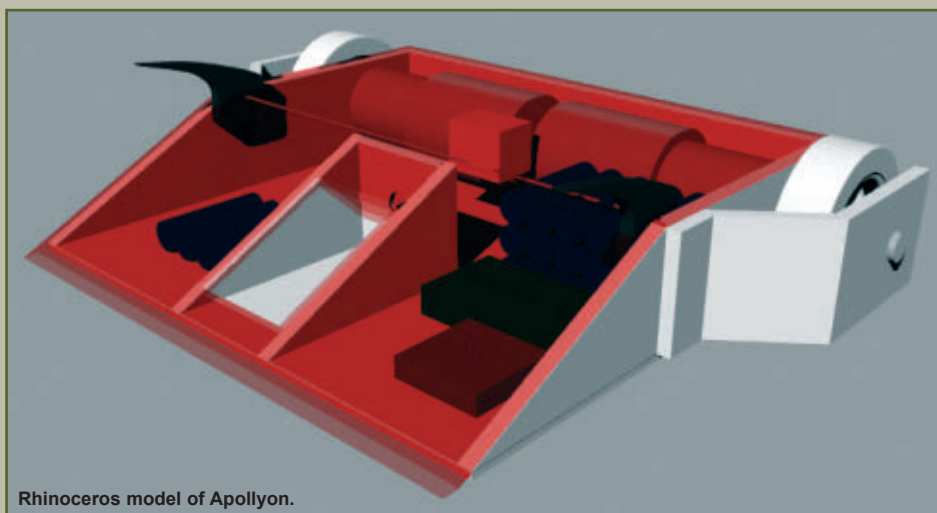
wiring to be done, and the robot eventually debuted at an event put on by Carolina Combat Robots called Wreck the Halls.

Apollyon went 3-1 at Wreck the Halls winning the 12 lb class. During the event, a few issues arose, however. The BEC used in Apollyon was not providing enough power to the receiver during moments of high current draw which resulted in the robot sitting dead for several seconds while the receiver restarted. Apollyon also took some heavy hits from Blunt Instrument and Surgical Strike at the event. The damage

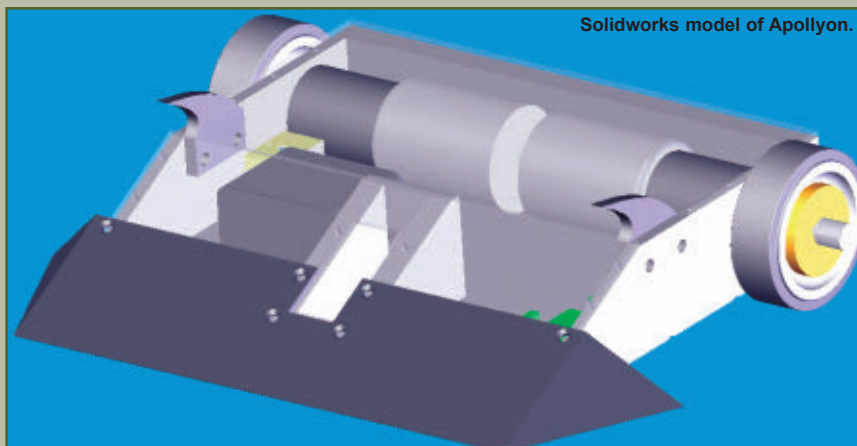
Apollyon took at Wreck the Halls led to the first design revision.

After having large pieces of the front of the chassis removed, I decided to extend the steel armor to the full height of the front of the robot. The new wedge was made from 4130 steel hardened to 45HRC.

With the new wedge came a new name and weight class. BattleBots was holding an event and among the classes was the 15 lb College class. Apollyon became Interstellar Overdrive and got some slight modifications for BattleBots. The first change was new batteries.



Rhinoceros model of Apollyon.



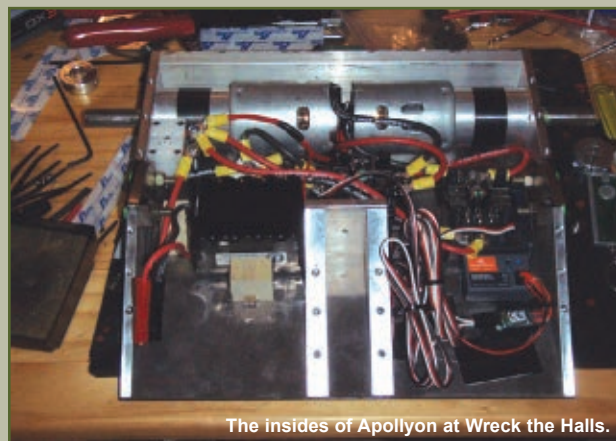
Solidworks model of Apollyon.



The chassis is starting to come together.



Apollyon is externally complete.



The insides of Apollyon at Wreck the Halls.

Apollyon used NiMH batteries to run, and the stress of the high powered motors fried the batteries in testing. Interstellar Overdrive was switched to a five cell A123 systems battery pack providing almost the same voltage, but much more current in the same weight. The other addition was the creation of a heavy and shock-mounted S7 steel

bumper that could be swapped in if the opponent called for it.

Interstellar Overdrive exceeded expectations at BattleBots. It ended the tournament with a 5-2 record, placing 4th overall and winning the award for best engineered 15 lb robot. This tournament also brought about the current design revision. In the 4th match, the gearbox on the

left side failed, leaving Interstellar Overdrive with one functional wheel. IO had previously lost its 3rd match which did most of the damage to the gearbox and was in the loser's bracket at the time. IO won the 4th, 5th, and 6th matches with a single drive wheel. This result should emphasize two things that are common pieces of



Apollyon shows the battle scars from Wreck the Halls.



Apollyon has a new wedge and is ready to fight again.



Interstellar Overdrive sporting a new wedge, rear bumper, and RIT decal.

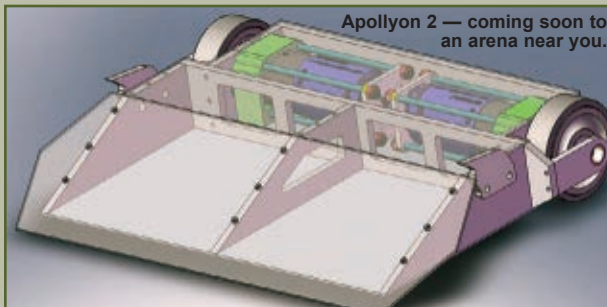
advice in the robot combat community: Always have spares and learn to “freaking” drive. IO retired in its 7th match.

The chassis was trashed and the gearboxes were dead or close to it. This was the perfect opportunity to redesign the robot, taking into account all the lessons that I’ve learned during the life of version 1.

For Apollyon/ Interstellar Overdrive 2, the discontinued gearboxes have been replaced with 18V Dewalt drills; the 6061 aluminum frame has been replaced with a blend of 2024 aluminum and garolite; and the



The battered remains of Interstellar Overdrive next to the trophy for best engineered 15 lb robot.



Apollyon 2 — coming soon to an arena near you.

front wedge and horns will be remade but will remain essentially the same. **SV**

EVENTS

Completed and Upcoming Events

Completed Events: July 5 - August 8

PA Bot Blast 2010 was presented by D.W. Robots in Bloomsburg, PA on July 17th.

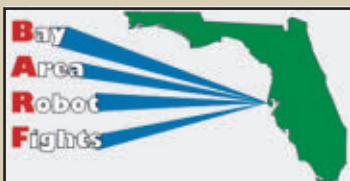


Schiele Museum Clash of the Bots was presented by Carolina Combat Robots in Gastonia, NC on July 24th.



Bay Area Robot Fights at Metrocon was held July 24th in

St. Petersburg, FL.



Upcoming Events: October - November

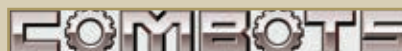
Mecha-Mayhem 2010 will be presented by the Chicago Robotic Combat Association in Rosemont, IL on October 23rd and 24th. Go to www.theCRCA.org for more information.



Robothon Robot Combat 2010 will be presented by Western Allied Robotics in Seattle, WA on October 24th. Go to www.westernalliedrobotics.com for more information.



ComBots Cup V will be presented by ComBots in San Mateo, CA, on October 23rd and 24th, 2010. Go to <http://robogames.net/registration/event/view/9> for more information. **SV**



EVENT REPORT: Robotic HORD Returns to Cuyahoga Valley Career Center

● by Chris Olin

The Ohio Robotics Club (ORC) — a member of the Robot Fighting League (RFL) hosted the House of Robotic Destruction (HORD) Spring 2010 at Cuyahoga Valley Career Center (CVCC) back in May of this year. This was the 11th event hosted by ORC and the 4th held at CVCC. Fourteen teams from five states brought 26 robots from the Flea (150 gram), Ant (1 lb), and Beetle (3 lb) weight classes to compete in a series of double elimination tournaments filled with mayhem and destruction.

CVCC students brought five robots to play, but only one of them finished with honors. CT Stompin, a cheese wedge bot driven primarily by Nick Staikoff, pushed its way to the semi-finals where it was then pitted with Meerkat Mreow, a rookie robot driven by Zach Witeof from Tipp City, OH. The CT Stompin crew took the third place prize, then dashed off to prom while Witeof advanced to the Ant weight finals where he faced ace driver Thomas Kenney and his highly acclaimed robot Gilbert. The Ant weight final was a fierce driving dual won by Kenney and Gilbert.

Kenney, a high school student from Franklin TN, proved his worth not only in the Ant weight



Winning drivers (left to right): Justin Gilkey, Thomas Kenney, Zach Witeof, Gene Burbeck, Chris Olin and Ron Barron.

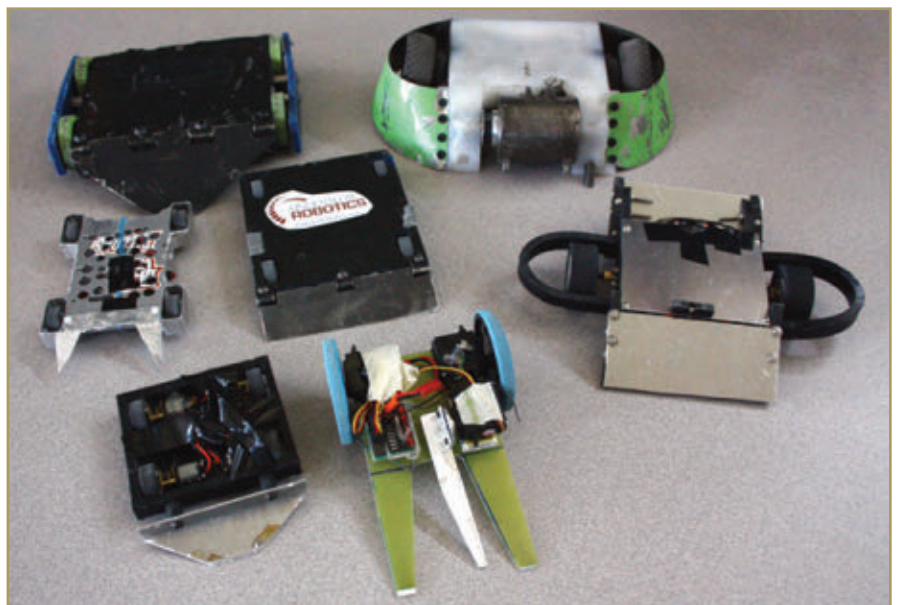
dominating eastern US competitions for the past two years.

The bright young minds of Bowling Green State University's Engineering Club came back for their second HORD, bringing two Flea weight robots: TunaBot, a full body spinner, and FalconBOT 2.0, a pusher bot built using the popular

Inertia-Lab's Ultralight Ant Chassis kit. TunaBot went 0-2, but FalconBOT 2.0, driven by Justin Gilkey and Erik Mayer, pushed its way to the loser's bracket semi-final where it lost to Mango Farmer for a second time.

ORC founders Chris Olin of Perry Township, OH and Ron Baron

class, but also by taking second place in the Flea weight class with Mango Farmer, and second place in the Beetle weight class with Cloud of Suspicion. Mango, Gilbert, and C.o.S. are all four wheeled pusher-wedge bots that dominate their weight classes. Kenney and his robots have been



Winning robots (right to left, top to bottom): Cloud of Suspicion, One Fierce Lawn Boy Beetle, FalconBOT 2.0, Gilbert, Meerkat Mreow, Mango Farmer, and Lefty.

(with helper Greg Shay) from Garrettsburg, OH each found time to run two robots while managing the event. Shay drove past Ant weight champion The Froogin, a low profile wedge-pusher, to a disappointing fifth place while Baron took control of his new under-cutter Beetle weight Nix which finished third. Meanwhile, Olin's servo-lifter Lab Assistant, another former champion, suffered even more disappointment and finished in seventh of 11. However, Olin's latest creation Lefty, a Flea weight with a servo drive train and a servo powered lifter arm — held

Ant weight rumble.



Rankings

FLEA WEIGHT

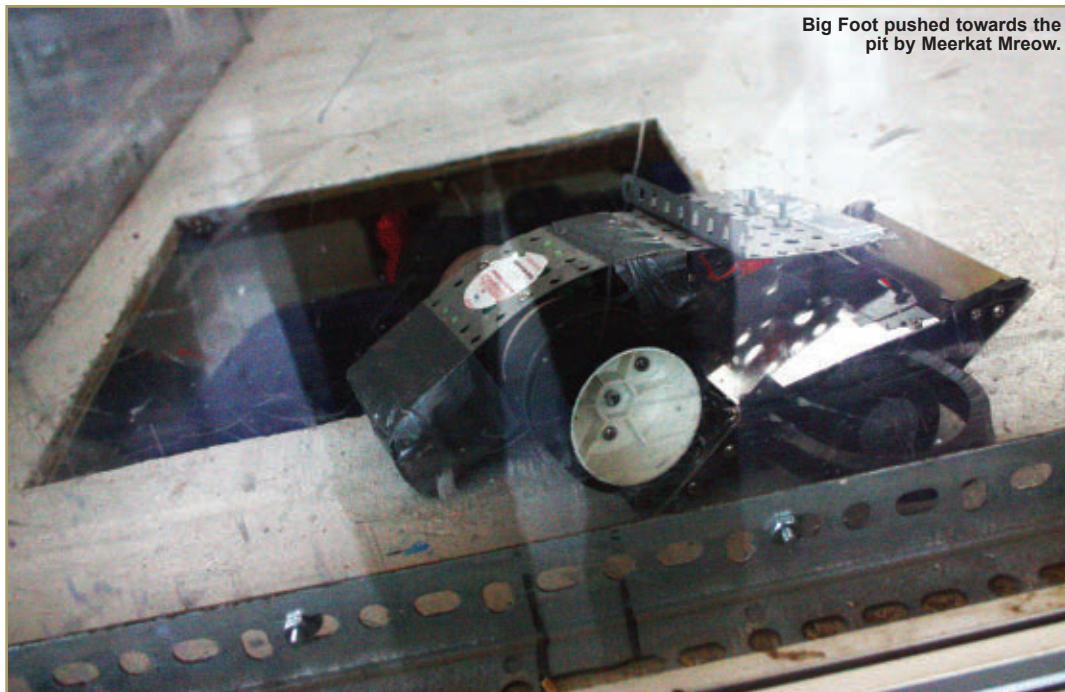
Rank	Bot Name	Driver	Team Name	City	State
1	Lefty	Chris Olin	Cloak & Dagger Robotics	Perry Township	OH
2	Mango Farmer	Thomas Kenney	MH Robotics	Franklin	TN
3	FalconBOT 2.0	Justin Gilkey & Erik Mayer	FalconBot	Bowling Green	OH
4	Underconstruction	Richard Kelley	Kelley PA	Boiling Springs	PA
5	Brutus	Dave Graham	Team Mateo	Gettysburg	PA
5	TunaBot	Various	FalconBot	Bowling Green	OH
7	Baby V	Dave Graham	Team Mateo	Gettysburg	PA

ANT WEIGHT

Rank	Bot Name	Driver	Team Name	City	State
1	Gilbert	Thomas Kenney	MH Robotics	Franklin	TN
2	Meerkat Mreow	Zach Witeof	Trojan Engineering	Tipp City	OH
3	CT Stompin	Nick Staikoff	CT Stompin	Broadview Heights	OH
4	Casper	Dave Graham	Team Mateo	Gettysburg	PA
5	Big Foot	Dave Graham	Team Mateo	Gettysburg	PA
5	The Froogin	Greg Shay	FishNecks	Garrettsville	OH
7	Dr. Super Brain's Lab Assistant	Chris Olin	Cloak & Dagger Robotics	Perry Township	OH
7	The Pill	Various	Independence HS	Independence	OH
9	THE Little ROLLING PIN	Richard Kelley	Kelley PA	Boiling Springs	PA
9	Don Quixote	Jesse Malone	CVCC Bots	Brecksville	OH
9	Bully	Don Jenkins	Team Labyrinth	Parma	OH

BEETLE WEIGHT

Rank	Bot Name	Driver	Team Name	City	State
1	One Fierce Lawn Boy Beetle	Gene Burbeck	Fierce Robots	Ann Arbor	MI
2	Cloud of Suspicion	Thomas Kenney	MH Robotics	Franklin	TN
3	Nix	Ron Baron	FishNecks	Garrettsville	OH
4	The Rolling Pin	Richard Kelley	Kelley PA	Boiling Springs	PA
5	Flat Line	Steve Russell	CVCC Bots	Brecksville	OH
5	One Fierce Round House	Gene Burbeck	Fierce Robots	Ann Arbor	MI
7	Carbon Chihuahua	Matthew DeHaven	Aperture Robotics	Poughkeepsie	NY
7	Prototype One	Adam Szechy	NRHS Robotics	North Royalton	OH



Big Foot pushed towards the pit by Meerkat Mreow.

Ann Arbor MI, Gene Burbeck and his twin engines of destruction, One Fierce Round House, and One Fierce Lawn Boy Beetle. Round House, equipped with a powerful under-cutter spinning disk, nearly wrecked Nix and the ORC arena before being pitted in early rounds. Round House went on to a quick victory and then another pitting, this time by Cloud of

together with tape and wishes — tossed the competition aside and finished in first place and was undefeated. Lefty defeated Kenney's Mango Farmer in the winner's bracket semi-final by

high-centering Mango on the arena bumpers, then won the finals by a technical knockout when Mango lost power.

The Beetle brackets were dominated by the mad genius from

Suspicion. Meanwhile Lawn Boy, armed with a frightening spinning drum, tore a path of destruction through the winner's bracket. Along the way, it defeated Cloud of Suspicion not once, but twice; first by bouncing S.o.C. off the arena ceiling and perching him on top of the bumpers, then in the final it K.O.'ed S.o.C. by dismemberment — proving once again sometimes brute force is the answer. **SV**



Cloud of Suspicion sent flying by One Fierce Lawn Boy Beetle.

Prizes and other considerations were provided by Dimension Engineering, FingerTech Robotics, and SERVO Magazine. Photography was done by Fenna Blue (www.short-girl.com).

ORC would like to thank CVCC, the RFL, their sponsors, photographer, volunteers, and competitors for helping put together a great event. ORC's next event will be at Classic RC Raceways in Akron, OH on September 25th. For more information on future ORC events see their website; www.ohiorobotclub.com.

EVENT REPORT: PA B t Blast 2010

● by Zac O'Donnell

July 17, 2010 fighting robots in four weight classes invaded the Columbia Mall in Bloomsburg, PA for the third annual PA Bot Blast. This event has always been very enjoyable and exciting. The prizes and trophies are fantastic, the eight-foot-square arena is top notch, and the organizer Jeremy and his team create a very entertaining atmosphere.

Registration this year totaled 28 machines — as many as the previous year — and there were even a few entrants that were not registered in advance. There were at least four different teams that were running three or more robots this year. A pleasantly surprising number of machines with active weapons were still fully functional late in the brackets. The effort required to keep the show entertaining for an extended period is nothing short of heroic.

With the exception of Scurrie, all robots in the 12 pound Hobbyweight class were new to this venue. Sparty and Hobo Vengeance from Team Rowdon looked like they had competed before but the other Hobbyweights were brand new. Several robots in the other weight classes were veterans of many competitions in Pennsylvania. After all of the machines in each weight class passed safety and the short meeting for the drivers was done, the brackets were created and the fights started.

In the first round of Hobbyweight fights, Scurrie and another 12 pound robot named Seppuku were both granted a bye. Hobo Vengeance fought the underweight AC-130 and Sparty fought the vertical thresher named Scavenger. Approximately a minute into each of their matches, the machines from Team Rowdon

started to become sluggish and unresponsive. Unfortunately, their battery packs were beyond their useful life. Luckily, a quick replacement in the pits put them back in the tournament. As with many issues in fighting robots, diagnosing the problem with the damaged batteries was more difficult than actually fixing it.

Despite weighing only approximately seven pounds, AC-130 continued to rampage through the winner's bracket, beating Scavenger and Seppuku to land itself in the Hobbyweight final. Scurrie had a tough loss in the second round against Scavenger when the weapon stopped working about a minute into the fight. Scavenger went on to beat Seppuku and Sparty before eventually losing to AC-130.

Scurrie fought its way through the loser's bracket, eventually facing Scavenger a second time, but this time Scurrie's weapon worked for

the whole match. Scavenger remained mobile until the end of the match, but the judges voted in favor of Scurrie so it went on to fight in the finals against the undefeated AC-130.

AC-130 controlled the first two minutes of the match, but Scurrie was then able to get past the dust pan for a knockout by blowing off a wheel

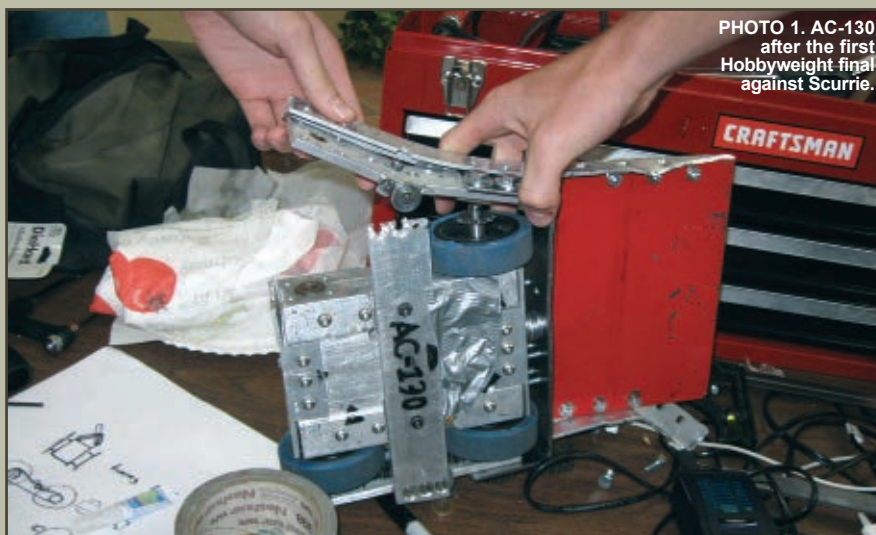
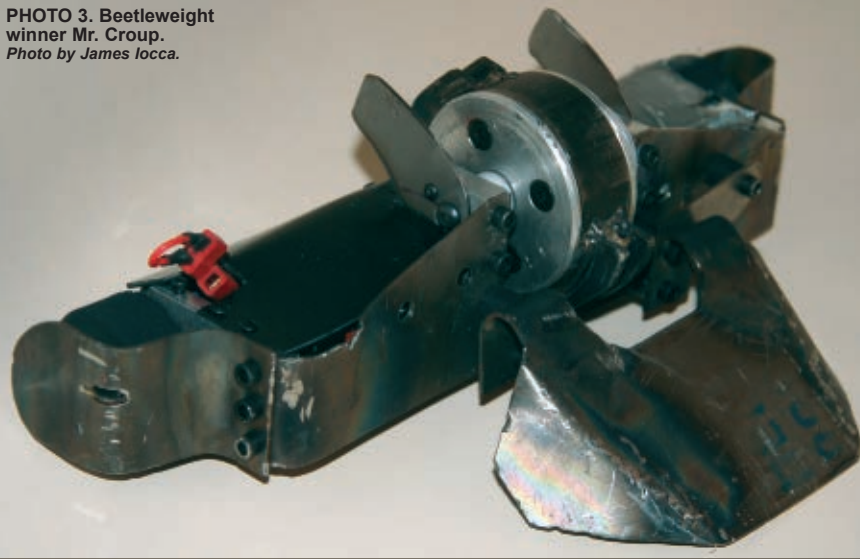


PHOTO 1. AC-130 after the first Hobbyweight final against Scurrie.



PHOTO 2. Hobbyweight winner Scurrie with "Angry Eyes" and trophies.

PHOTO 3. Beetleweight winner Mr. Croup.
Photo by James Iocca.



and one side of the armor. The damage from the fight can be seen in **Photo 1**. Because that was the first loss for AC-130 in the double elimination tournament, the AC-130 team hurried to repair the damage and was able to get ready to go for the final fight.

The second fight was similar to the first, with Scurrie getting in a couple of decent hits and eventually knocking AC-130 out. **Photo 2** shows the trophies and match winner chips that Scurrie earned.

A couple of noteworthy machines in the lighter weight classes

were Mr. Croup and Fangus 3.0. Mr. Croup was the three pound Beetleweight champion (**Photo 3**) who sported very sleek floating and shock-mounted titanium armor and a large vertical disk. Fangus 3.0 won the one pound Antweight title with a very effective implementation of a shuffling drive system instead of wheels. The shuffling mechanism worked flawlessly and Fangus 3.0 was able to bounce two different opponents off of the ceiling of the box.

True to its name, the competition really was a blast with great sportsmanship and entertaining fights. The event was well organized, well equipped, and in a great location for the Northeastern contingent of robot builders. No admission fees and lots of parking around the Columbia Mall meant that there was no reason to miss next year's competition. For videos of many of the fights from this year — including some high-speed footage — search Youtube for "Bot Blast 2010." **SV**

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Melty Brains

by Kevin Berry and Sean Canfield

What Dave saw
just before he
dived into the
Obelisk nine
years ago ...



"The thing's hollow—
it goes on forever—
and—oh my God—
it's full of stars!"

Thanks to Team Busted Nuts Robotics. Photo by Mike Gellatly. Busted Nuts is Mike, Adam Bercu, and Paul Grata. Witch Doctor vs Fuchsia Fusion at BotsIQ 2010 in Miami. Caption created by Jason Bardis.

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HOVERBOT:

Look Ma, No Wheels!

By Paul Verhage



What wears a skirt and floats on a cushion of air? The HoverBot, of course! Last month, we discussed how to build the airframe and nozzle of a floating robot. This month, we'll dress the HoverBot in a skirt and add its drive fans. When you finish next month, your HoverBot will behave a lot like a two-dimensional satellite in weightlessness. So, here's that chance to test those satellite control procedures you've been talking about.

The HoverBot's skirt is a plastic bag mounted beneath the robot. It forms a seal with the ground that forces air from the lift fan to create a uniform, low friction cushion of air beneath the HoverBot. If, however, the skirt's seal isn't uniform all the way around the HoverBot, air jets out one side and the robot crashes to the ground. This can be a significant problem when the ground is not uniformly

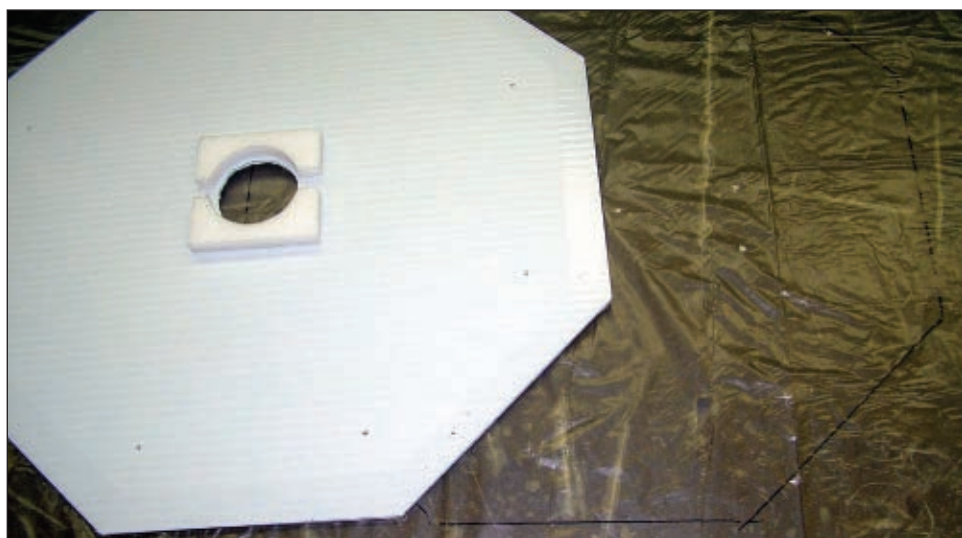
smooth. Therefore, in order for the HoverBot's skirt to adapt to variations in the terrain, the skirt is made from a flexible material. In this case, 0.7 mil thick plastic sheet. Inexpensive drop cloth uses plastic sheeting this thick and it's available wherever household painting supplies are sold, including big box retailers. While you're picking up your plastic drop cloth, also get a Sharpie pen, a metal straight edge, clear packaging tape (the two inch wide clear tape used for sealing packages before they can be mailed), and



I used this straight edge and Sharpie to draw the lines on this sheet of 0.7 mil thick plastic.



The smallest octagon is the same size as the bottom deck – 16 inches across. The next octagon is 2-1/2 inches larger in diameter (1-1/4 inches larger in radius) and marks where the skirt will tape to the edge of the bottom deck. The last and largest octagon is 2-1/2 inches larger still and is the edge of the skirt. You'll cut the skirt out on this line.



This photograph was from an early test of the HoverBot; the riser bolts had not been added to the bottom deck when the skirt's first octagon was drawn. However, you'll draw the outline of the bottom deck onto the 0.7 mil plastic while the riser bolts are attached to the bottom deck.

an Exacto knife. Then when you get back, separate the top and bottom decks of the HoverBot. You'll only need the bottom deck to make the skirt. You'll use the top deck later when you mount the drive fans.

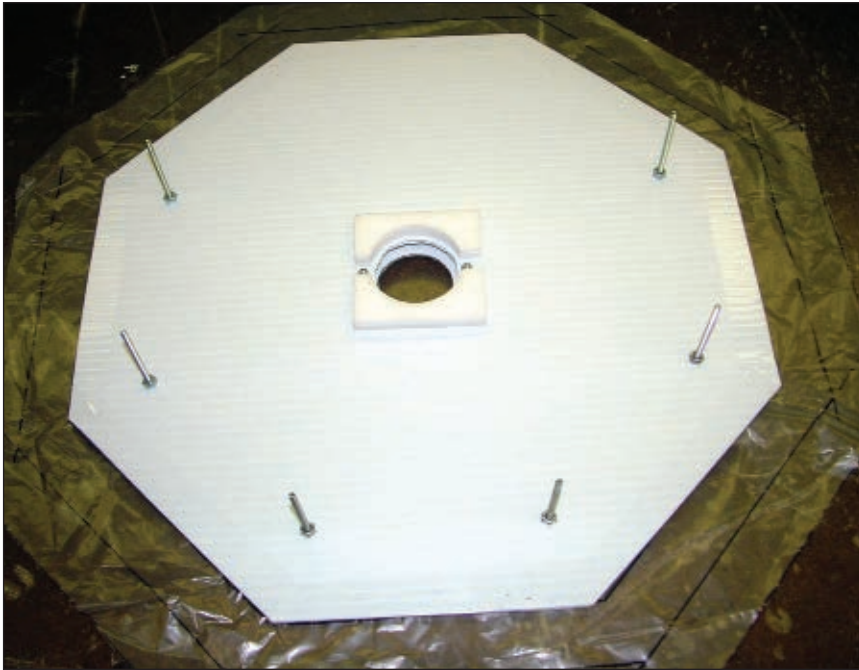
Making the Skirt

Find a large surface to work on because you'll need to

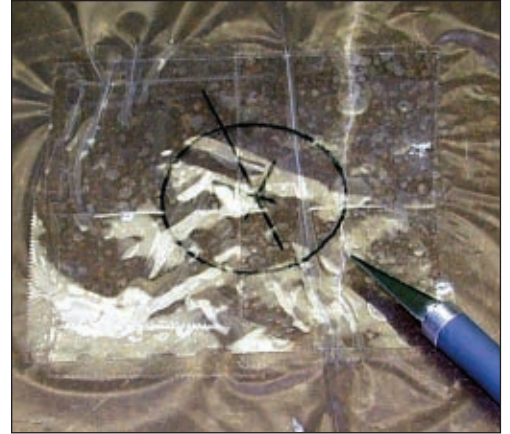
draw the outline of the bottom deck onto the plastic drop cloth; it's 16 inches across. The drop cloth comes in a huge amount, so cut off a hunk of the stuff first. Since the bottom deck is 16 inches wide and you'll need to add a border to the skirt, cut off a piece of plastic that's two feet square. You're going to have enough plastic drop cloth left over to make a fleet of HoverBots.

Lay the plastic on a flat surface and place the HoverBot's bottom deck over the center of the skirt material. Use a Sharpie to draw the outline of the octagonal-shaped bottom deck. Draw neatly; you want the skirt to be as symmetrical as possible and you're going to build up the skirt's outlines from this first octagon you're drawing.

Don't cut the skirt out yet! You still need to add additional width to the octagon in order for the skirt to billow. I used my straight edge to draw a 1-1/4 inch wide border around the octagon. Why a 1-1/4 inch border around the octagon for the billow? That's because 1-1/4 inches is the width of my straight edge. You may want to experiment with adding different border widths for the billow (remember, you have skirt material left over for



I've laid the bottom deck on top of a skirt to verify the skirt is properly sized and even all the way around.



Don't add more tape than necessary. The taped area of the skirt should not extend much beyond the nozzle plates. Don't worry about measuring the size of the tape at a microscopic level of precision.



I only drew the diagonal lines near the center of the skirt as I didn't want the lines across the entire skirt. There's no reason you can't have corner to corner lines in your skirt; they might even look neat if drawn in a variety of colors.

dozens of experiments). If you try different amounts of billow, please contact me to let me know how it went.

To make the border as uniform as possible, lay one side of your straight edge up against the edge of the octagon

drawn on the plastic and draw a larger, concentric octagon using the opposite edge of the straight edge. That way, you don't have to measure 1-1/4 inches beyond the first octagon to draw the second larger, concentric octagon.

But wait; don't cut the skirt out just yet! You need to draw a third and larger octagon around the two concentric octagons you already drew on the plastic sheet. The largest octagon is where you will cut out the skirt. Since you have a straight edge handy, use it a second time to draw the edges of the skirt. So again, lay the straight edge alongside the second octagon and draw another, larger octagon. Now you have three nested octagons that should look like the **image** shown here.

Now you can cut out the skirt on the outermost octagon. I used the Exacto knife and straight edge to make a clean cut. A pair of sharp scissors will do the same.

Attaching the Nozzle to the Skirt

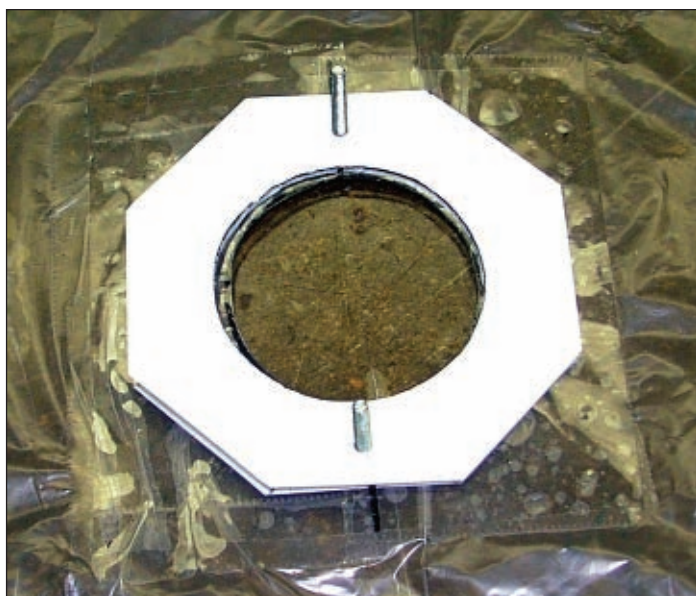
You're not ready to affix the skirt to the bottom deck yet; you must attach the nozzle to the skirt before mounting it. Begin by removing the nozzle from the bottom



Use an Exacto knife to carefully cut out the nozzle hole in the reinforced skirt.



This is the underside view of the skirt and mounted nozzle. Notice there's a gap between the nozzle plates and the bottom deck. This gap is where air fills the skirt to make it billow and hug the ground.



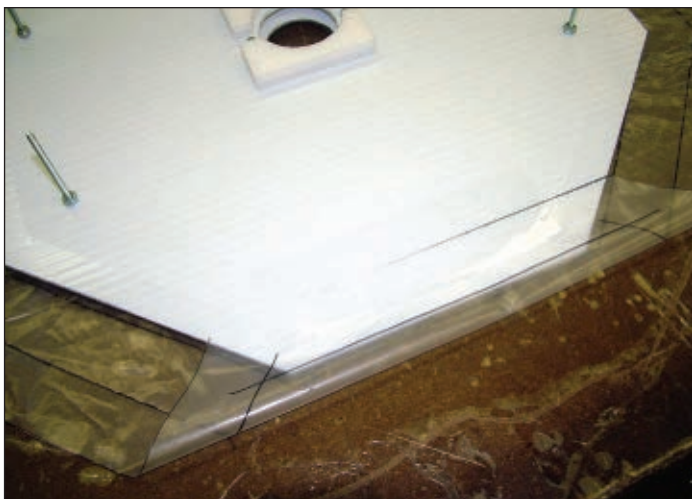
The plastic skirt is sandwiched between the top and bottom plates of the nozzle. After slipping the plastic spacers over the bolts, the nozzle will be bolted to the underside of the HoverBot's bottom deck.

deck and set its mounting hardware (bolts, nuts, and plastic spacers) aside where you won't lose it. All you need right now is one plastic octagonal nozzle plate. Since the nozzle is centered on the bottom deck, it's also centered on the skirt. The easiest way to find the center of the octagonal

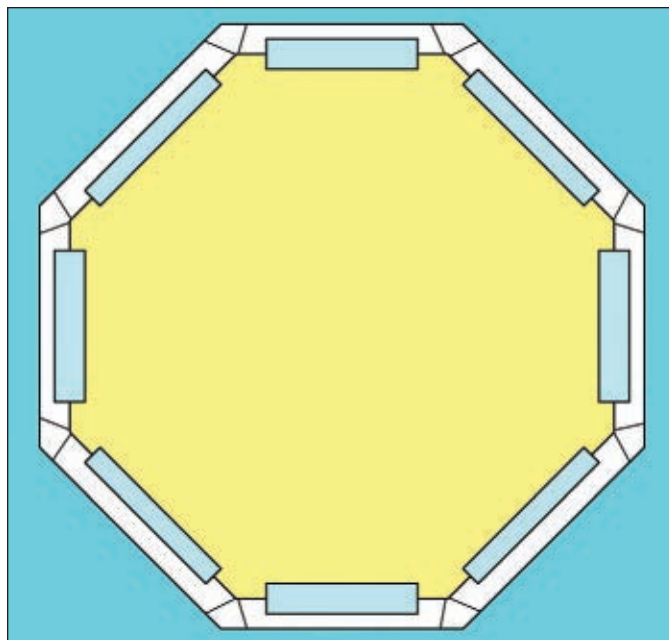
skirt is to draw lines across two pairs of corners and see where they intersect. At that intersection, center the nozzle and draw the outline of the round hole of the nozzle on the plastic skirt. Don't draw the outside shape of the nozzle on the skirt — it's not needed.

The skirt material is sandwiched between the plates of the nozzle and then bolted to the bottom deck. However, the skirt's 0.7 mil thick plastic won't stand up to bolts and air blasts without ripping, so you're going to use some packing tape to reinforce the nozzle area of the skirt. Apply a layer of clear packaging tape to the top and bottom sides of the skirt. Use enough tape to cover an area a little bit larger than the nozzle plates, but not much larger. I suspect that if the tape reinforcement covers a large area, it will make the skirt stiff and reduce its ability to conform to the ground. So in my HoverBot, the reinforced area does not extend more than a 1/4 inch beyond the nozzle plates.

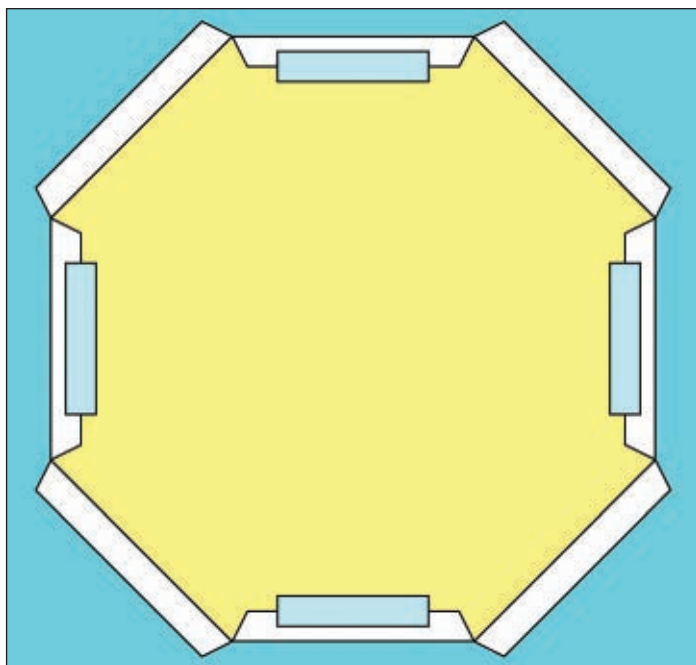
Next, drill or cut out two holes in the reinforced skirt for the nozzle bolts. These are the two 4-40 bolts that hold the nozzle away from the bottom deck. However, before drilling the two holes, align the skirt to the deck so their octagonal shapes line up. If you don't align the skirt to the deck before drilling the mounting holes, then mounting the nozzle to the skirt will probably twist the skirt so its octagonal shape does not fit the deck. Check your alignment and mark the location of the nozzle mounting



Notice the edge of the skirt's second octagon is aligned with the edge of the bottom deck. Use a piece of clear packing tape to tape this octant to the upper face of the bottom deck.



The middle six inches of all eight octants has been taped to the upper side of the bottom deck. Next, you'll tuck the corners neatly and tape them.



Only four octants of the skirt are taped to the bottom deck at this point. This image may make it look like the skirt has been cut between octants, but it's not. The skirt is still an octagon with no clipped edges. Note that the middle six inches (or so) of each segment have been taped to the bottom deck.

holes on the skirt. Afterwards, drill or cut the holes carefully so you don't tear the skirt. Now sandwich the skirt between the two nozzle plates and then run the bolts through the plates. Slide the spacers on the nozzle bolts and attach the nozzle to the bottom deck with its bolts and stand-offs. Use nylocks to permanently attach the nozzle to the bottom deck (you don't want the fans to vibrate any nuts loose).

Mounting the Skirt to the Deck

Now that the nozzle is bolted to the underside of the bottom deck, it's time to attach the rest of the skirt. The skirt folds over the edge of the bottom deck where it is then taped to the top surface of the bottom deck. You'll do this in a single octant at a time so the skirt is taped as evenly as possible to the bottom deck. Take one edge of the skirt from the underside of the bottom deck and fold it over to the upper side of the bottom deck.

Remember the three concentric octagons you drew on the skirt? The inner octagon was drawn the size of the bottom deck and you ignore that one. Take the second

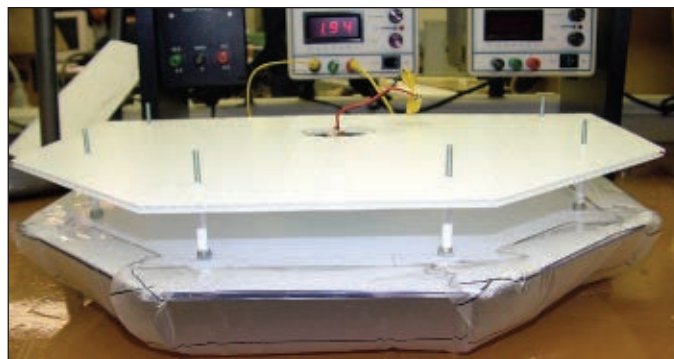


I tried to wrap the skirt evenly around the bottom deck as I taped it down. Okay, so I was only partially successful. Make sure the packaging tape covers any possible openings in the skirt that could let air escape from the upper side of the bottom deck. Any air leaving the skirt through the top is air that doesn't inflate the skirt or lift the HoverBot.

largest octagon and line up its edge with the edge of the bottom deck. Do not tape the entire length of the octant to the upper side of the bottom deck just yet. Only use about six inches of tape to attach the middle six inches of the first octant to the deck. Since only this section is taped to the deck, the ends of the octant are loose. You'll tape them down later. Try to minimize the wrinkles as you tape it down because I suspect that wrinkles in the skirt can result in creases that prevent the skirt from sealing uniformly to the floor.

Now tape the skirt's opposite octant to the upper side of the HoverBot's bottom deck. Again, align the edge of the second largest octagon to the edge of the bottom deck and keep your work neat. Only tape the middle six inches of the octant — do not let the tape extend to the end of the octant.

Repeat two more times by taping the two octants at right angles to the octants that have already been taped



In this early model of the HoverBot, I found out that when the top deck is too large, the HoverBot does not glide well. Notice that the HoverBot's skirt is fully inflated with air and fairly symmetrical in this picture.

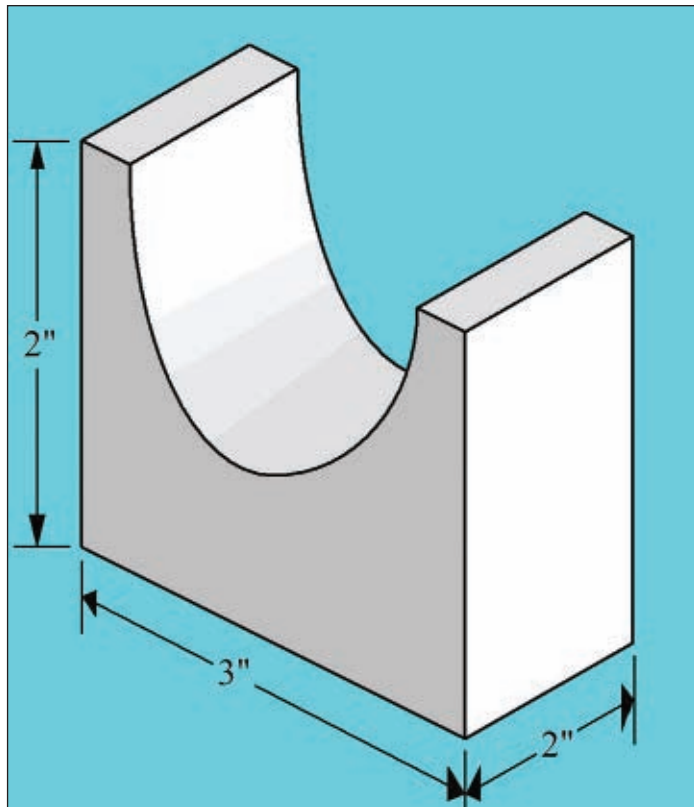
down. As with the previous two octants, only tape the middle six inches to the bottom deck. (You are only taping the alternating skirt octants to the bottom deck at this time.) Now it's time to tape the alternative octants to the deck. Fold one of the free octants to the deck, line the edge of the middle (second largest) octagon to the edge of the deck, and tape the middle six inches of this octant to the deck. Repeat this for the remaining three octants. Again, only tape the middle six inches. This leaves eight corners between each octant un-taped to the bottom deck.

Now fold up each corner as neatly and symmetrically as possible and apply a small piece of tape to it.

After taping the skirt's eight corners to the bottom deck with a bit of tape, apply additional tape to the skirt to completely seal the skirt. Evenly distribute any loose bits of skirt around the bottom deck as you finish taping it.

While not necessary, you can run a test on the skirt by putting the HoverBot together and powering the lift fan with a power supply or battery. To do this, slide the lift fan into the clamp in the bottom deck. Put the spacers on the four riser bolts. Pass the ducted fan's wires through the opening in the top deck and mount the top deck to the bottom deck. The lift fan will be held snugly by the clamps on the top and bottom deck, and the top deck will sit nicely on the spacers on the risers.

Now give the lift fan five or six volts. It will draw nearly two amps in the process. The skirt will inflate and a cushion of air will magically appear beneath the HoverBot, lifting it off the ground. A gentle push will send the HoverBot across the table.



These are the dimensions of the drive fan brackets. The brackets are Styrofoam and easy to cut with a hot knife. The Hobby Lobby sells the perfect electric knife next to the Cellfoam 88.

Adding Drive Fans

The lift fan fills the skirt to create an even seal to the floor and the cushion of air that the HoverBot will ride on. However, what drives and steers the HoverBot? There are two additional fans — the drive fans — mounted to the top of the top deck that act as the wheels and motors of the HoverBot. The GWS company mounts the ducted fans in the interior of a Styrofoam airplane fuselage. They don't use or even make brackets for the fans — the Styrofoam fuselage is shaped into a bracket that holds the ducted fan. Therefore, you'll have to make our own brackets for the HoverBot's drive fans. For this, I selected blocks of two inch thick Styrofoam; the kind of blue Styrofoam sheeting used in house insulation.

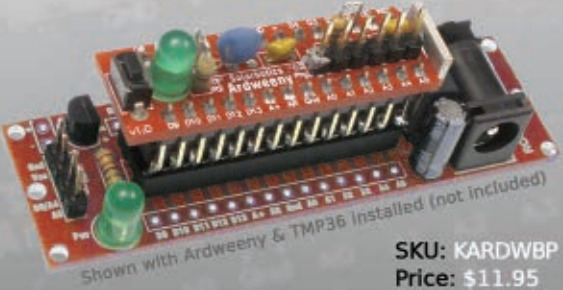
Cut two blocks of two inch thick Styrofoam measuring three inches wide and two inches tall. Find the center of the block's three inch long face and draw a vertical line. Use a circle template (or make one with a compass and index card) to draw a semi-circle at the top of the block (on the three inch wide face). The ducted fan is 2-1/8 inches in diameter, so use a circle template 2-1/4 inches in diameter. Draw the semi-circle at the top of the block and centered on the vertical line you just drew. Then, use a hot knife to cut the semi-circles out of the top of the Styrofoam blocks. The fan will lie on its side inside this bracket with a little clearance all the way around.

After cutting out the two drive fan brackets, use hot glue to mount them to the top side of the top deck. I mounted my drive fan brackets at the ends of the top deck; however, they don't have to be that far out. As long as the drive fan brackets are glued the same distance from the center of the top deck, they'll be fine. However, I recommend gluing the brackets near the ends of the top deck so the drive fans are more effective at steering the HoverBot (further out and they generate a larger torque on the HoverBot).

After the hot glue has cooled, glue the ducted fans to their brackets. The plastic housing or jacket of the ducted fans are made of flexible plastic and can be warped when you squeeze them. If a ducted

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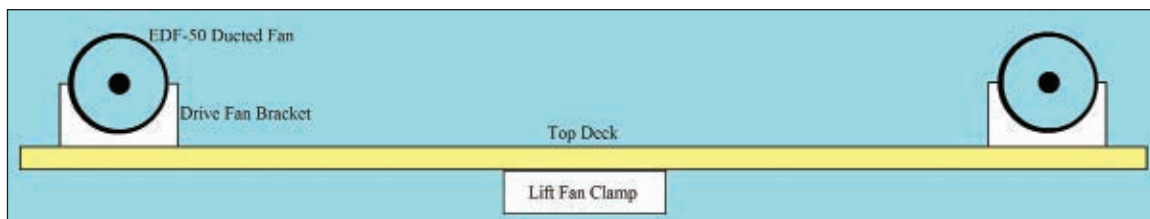
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P5- We were going to mention broken C-3PO on Chewbacca, but that was more of a mesh than a backpack.



This is a front view of the top deck with its two drive fans glued to it. At the bottom is the Styrofoam block that clamps the lifting fan to the top deck. There's a large space between the fans; next month's article will discuss the electronics that will fill this space.



fan's housing is bent out of shape, the blades of the fan will not spin freely since they will rub against the wall of the jacket. Apply some hot glue into the semi-circular canal in the bracket and gently set the fan into the bracket. Make sure the fans face the same direction. Let the glue cool. Note that it does not take much hot glue to hold the ducted fans into place. The fans will push the HoverBot but not too strongly that they rip themselves out of their brackets.

Now give everything a test fit. Slide the plastic spacers over the riser bolts in the bottom deck. Place the lift fan into the lift fan bracket on the bottom deck and pass its wires through the opening in the top deck as you mount the top deck on the bottom deck. As you mount the top deck, the lift fan clamp on the top deck will slip tightly over the top of the lift fan. Make sure the top deck sits flush to the spacers on the riser bolts and that the lift fan is snugly trapped between the lift fan clamps glued to the top and bottom deck. If this all looks good, then you'll be ready for next month's article that will discuss the electronics that operate the HoverBot. **SV**

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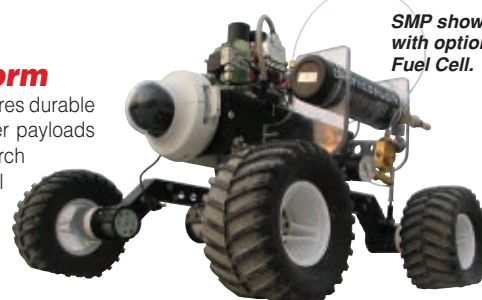
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SMP shown with optional Fuel Cell.

The NXT

Big Thing #3

See The Light!

By Greg Intermaggio

Last month, we learned how to add a touch sensor to Eddie — our EDucational robot.

This time, we'll learn about the light sensor which many NXT enthusiasts argue is the single most versatile sensor available for the kit.



We'll start by getting a broader understanding of the light sensor and its functions.

- What exactly does a light sensor sense?
- What are some practical applications for a light sensor in consumer electronics?
- How can we use the light sensor within the NXT system to learn more about robotics?

After answering these questions, we'll build two light sensor attachments for our robot: one using just one light sensor, and a second with two light sensors.

If you only have one light sensor, have no fear! We'll be focusing on the single light sensor attachment, offering the double light sensor attachment as a challenge! Next time, we'll be covering multiple sensor programs, so you may want to purchase an extra light sensor from LEGO Education (<http://bit.ly/lightsensor>).

What exactly does a light sensor sense?

A light sensor uses a photovoltaic cell to detect the intensity of the light it is exposed to. It can sense either reflected light (light originating from the sensor itself and reflected off the nearest surface) or ambient light which is light naturally existing in the robot's environment. To put it simply, a light sensor will sense the intensity of light that it is exposed to, whether by itself or its environment.

What are some practical applications for a light sensor in consumer electronics?

Probably the most common use of photovoltaic (light sensitive) cells in consumer electronics are street lamps that turn on automatically at night. If you've ever been down a road at dusk and watched different streetlamps turn on and off at different times, it's more than likely small variations and imperfections in the photocells are causing them to turn the lights on at a different threshold.

Beyond that, light sensors have many more interesting applications. Lots of cellphones are now equipped with light sensors to save battery life — screens need to be brighter during the day to be visible, but at night it's not necessary, so screens dim automatically to save power.

How can we use the light sensor within the NXT system to learn more about robotics?

We could certainly make a LEGO street lamp or a LEGO automatic dimmer switch, but that would be boring! We'll be taking a much more hands-on approach to learning about the light sensor by creating several programs that move and react based on the readings received.

Now, let's get building!

1. First, find a long perpendicular axle joiner.



Single Light Sensor Attachment Building Instructions



Slide a three-stud axle through the axle joiner.

2.



Push two standard perpendicular axle joiners onto the open edges of the three-stud axle.

3.



Snap in long friction pegs with axle holes as indicated.

4.



5. Add two standard friction pegs into the long perpendicular axle joiner.



6. Attach a studless L-beam to the friction pegs.



7. Snap in two standard friction pegs as indicated.



8. Attach the light sensor.

Double Light Sensor Attachment Building Instructions



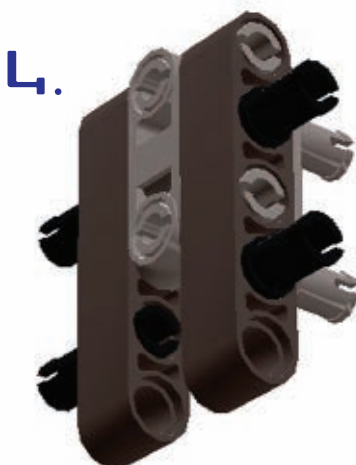
1. Start with a 3x3 double peg.



2. Attached an identical 3x3 double peg perpendicular to the first.



3. Snap in five-hole studless beams on either side of the second double peg.



4. Affix two standard friction pegs on each side of the assembly.



5. Attach the light sensors to complete the assembly.

Testing the Light Sensor

Attach the single light sensor assembly to the front of the robot as indicated in **Figure 1**. Hook it up to sensor port 1. Now, we'll do some tests.

- Power the NXT on and navigate to the "View" menu.
- Select "Reflected Light" > "Port 1."

At this point, you'll need a light surface with a dark line (tape) or a dark surface with a light line. LEGO Education sells several mats that are great for light sensor testing, one of which can be found at <http://bit.ly/legomat>.

Once you've prepared your surface and line, put the robot over the surface and look at the screen. If your surface is white, your reading from the light sensor should be somewhere between 45-65%. Now, move the robot over the line. If the line is black, it should give a reading of 20-40%.

If your lighter surface is giving a higher reading than your darker one, that means your light sensor is working correctly and you're ready to move on to programming. If you're having trouble with sporadic readings or inconsistency, double-check that your light sensor is connected to the right port, you're using "Reflected Light" and not "Ambient Light," and you have the correct port selected on the NXT.

Before we get to programming, you'll need to decide on your threshold number. This number is important because we'll be telling the robot to wait for the light readings to cross that threshold before performing actions. To find your threshold number, add the value of your dark surface to the value of your light surface, and divide the sum by 2. This value will put us perfectly between the values of light and dark, meaning that the robot will be as accurate as possible in detecting the line.

Stopping at a Line

Let's try a simple program. We'll make Eddie move forward until he hits a black line. **Figure 2** is a diagram of the actions we want the robot to perform. **Figure 3** is the program. Note the programming logic:

- Motors C and B go backward (meaning the robot goes forward) indefinitely.
- Wait for reflected light on port 1 under threshold (if detecting black line) or over threshold (if detecting white line).
- Stop motors C and B.

Time for something a little more exciting!

Sumo!

One of the most popular LEGO robotics competitions is Sumo, where robots go head to head in an attempt to push

Figure 1.

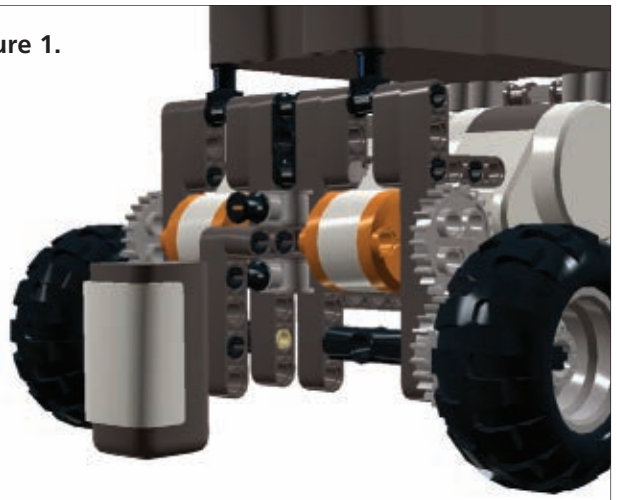


Figure 2.

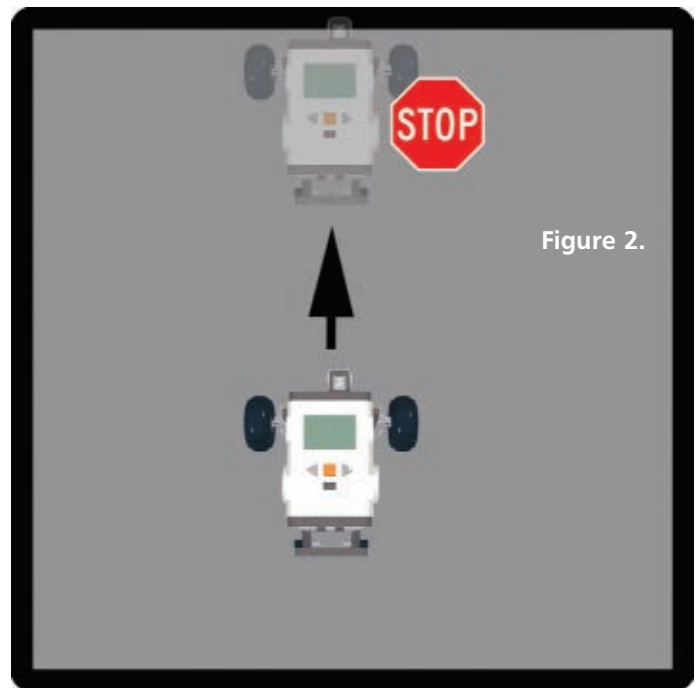
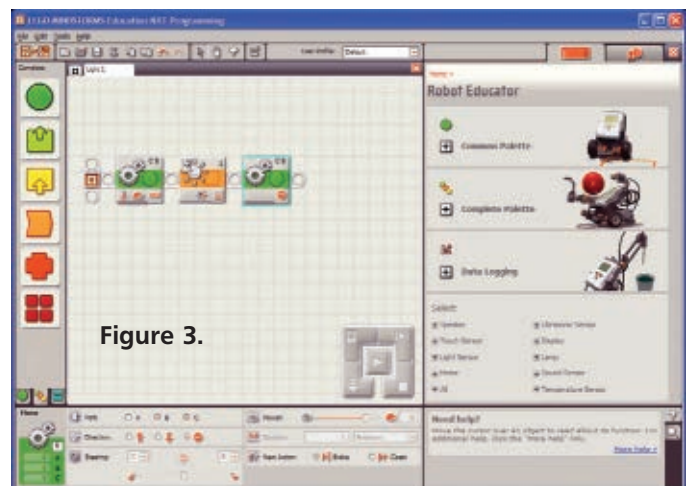


Figure 3.



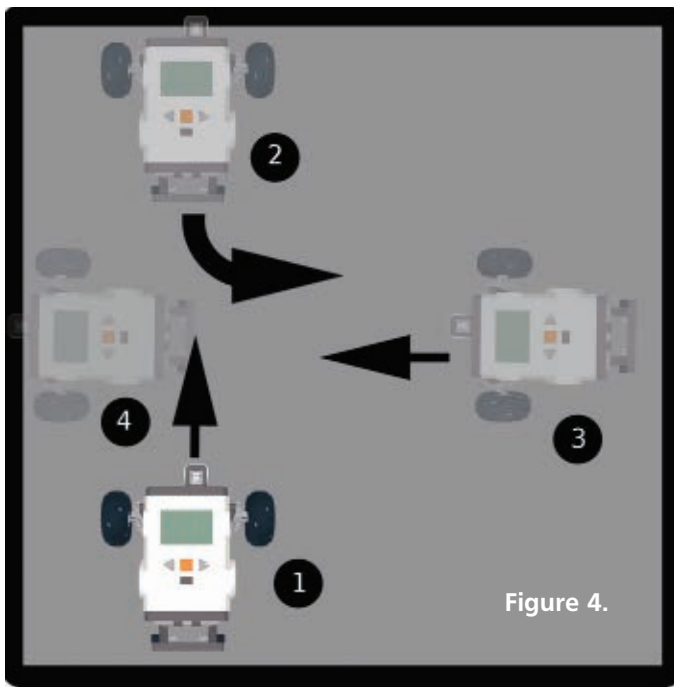


Figure 4.

each other from a ring. It's a lot of fun and a great way to learn about good engineering and programming. Not only do the robots need to be built well and geared for torque, they need to have a program to keep them inside the ring at all times. **Figure 4** shows approximately what a Sumo robot should do.

- 1) Move forward until black line.
- 2) Reverse and turn (either direction).
- 3) Move forward until black line.
- 4) Repeat.

Figure 5 shows the program for our Sumo bot. Its steps are very similar to the logic we saw in **Figure 4**:

- Motors C and B go backwards (robot goes forwards) indefinitely.
- Wait for reflected light on port 1 under threshold.

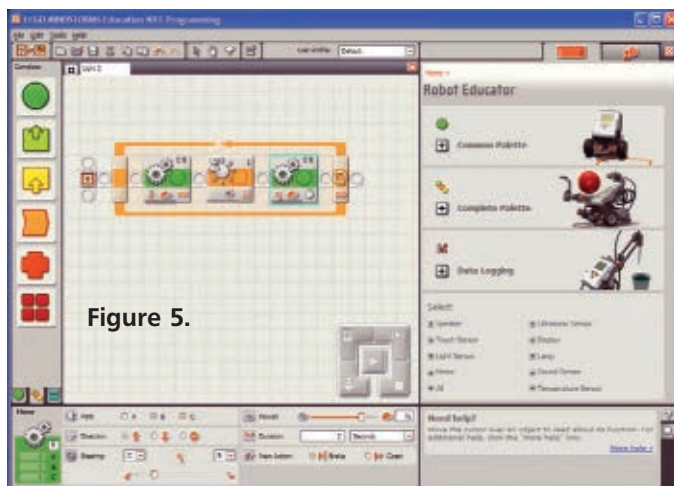


Figure 5.



Figure 6.

- Motors C and B go forwards (robot goes backwards) and turns slightly for two seconds.
- Loop to first step.

Single Light Sensor Following

Now that we've gotten a couple programs under our belt, let's try to make a robot that follows a line, continuing to use our single light sensor attachment. **Figure 6** shows the path our robot will follow:

- 1) Move forward until black line.
- 2) Turn left until light.
- 3) Turn right until black line.
- x) Loop Steps 2 and 3.

Figure 7 shows our single light sensor line follower.

Challenge

Now that you've experimented with a single light sensor, try to make a program that uses the double light sensor attachment to follow the line more accurately. Share your program with friends and compete for the fastest time trial on a lengthy course. If you have trouble, come back next time where we'll be covering programs using multiple sensors.

If you've enjoyed The NXT Big Thing so far and want to see more articles featuring the MINDSTORMS NXT, please take a second to let *SERVO* know via editor@servo magazine.com. Thanks for reading! See you next time! **SV**

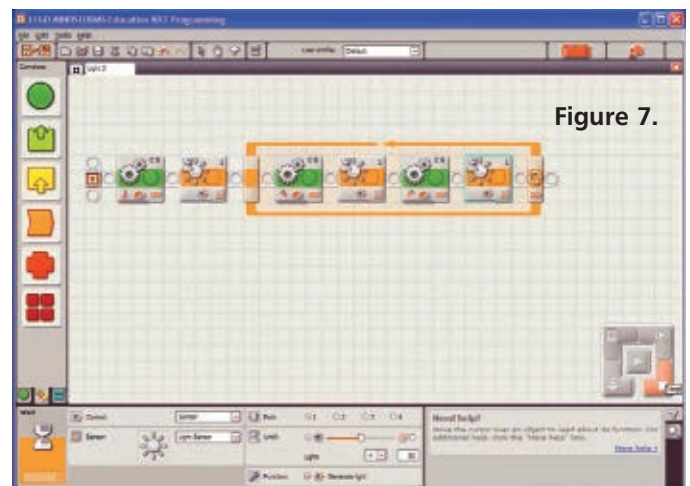


Figure 7.

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More Room for Your Robot Stuff

By Fred Eady



I finally had gone high tech. I had just purchased my very first hard drive. The cost ... \$50 for a full-sized 5 MB drive. Within a few days, I had managed to convince my IBM 5150 PC to give up one of its full-sized 160 KB 5.25 inch floppy drive slots for the high-capacity 5 MB hard drive. My 5150 was highly modified. After throwing away the original 8088 and replacing it with a newer and faster NEC V20, I cranked up the original 4.77 MHz CPU clock frequency to 8 MHz and installed a set of 5160 BIOS ROMs. The 5160 was called the XT at that time and came standard with a 10 MB hard drive. If you had more money than you could stand, you could opt to purchase the expansion unit which enabled you to install up to two more 10 MB drives. Installing a mux IC and activating a jumper allowed me to take the motherboard memory up to the maximum of 640 KB. Things were good and Microsoft was king.

The 8088 and NEC V20 could not stand totally alone. Both microprocessors required external "helper" ICs to operate. I just pushed a 2 GB MicroSD card into its socket which is under the control of a PIC18F46J50 microcontroller that is standing alone and running at 48 MHz. Things are good and Microsoft is still king. That MicroSD card I just installed stores files in the Microsoft FAT format.

5150 Capability in a Microcontroller?

Before I wedged in that 5 MB hard drive, my trusty old 5150 booted Bill's DOS from floppy disk A:. All of the 5150's hardware drivers (BIOS) were loaded into a couple of ROMs, and DOS or any other program loaded into the 5150's memory depended on being able to access the BIOS services. The same computing paradigm that my 5150 used is still being used in today's PCs. The difference is that modern PCs store their BIOS routines in Flash or EEPROM. Instead of installing a new set of ROMs, BIOS is changed or updated by downloading new firmware to the BIOS media via a loader program running on the PC itself.

Hard drives and floppy drives are not normal participants in smaller embedded environments under the control of a microcontroller. However, that same 5150 computing paradigm can be a useful addition to a small microcontroller-based embedded system. In most instances, a microcontroller application is coded, assembled, linked, and programmed into the microcontroller's program Flash. The microcontroller application does not change unless the microcontroller is reprogrammed with a differing piece of application firmware. If we were to allocate a portion of the microcontroller's program Flash area for a nonvolatile resident sub-application that could load an application into the microcontroller's program Flash on the fly, we could load and run differing embedded programs in the same manner as we do on a laptop or desktop PC.

The 5150's applications lived in RAM. Thus, the "program memory area" of the 5150 being RAM could be read, written, and erased at will. For the 5150 boot device paradigm to work in a microcontroller, the microcontroller's program Flash must also be able to be read, written, and erased just like the 5150's RAM. Most all of the new PIC microcontrollers have the capability to read, write, and erase their program Flash areas without any external assistance. Thus, if we can select a suitable PIC to interface to the MicroSD card hardware, allocate a bootloader program area, and write some bootloader code, we can load applications saved on the MicroSD card into the PIC. That one-trick robot now has the capability of loading and running any application that it can access from the MicroSD card.

Building a Bootloader

PCs have operating systems such as Windows and Linux that provide the power behind moving data between storage devices and the CPU complex. In the case of the

PIC, the power wielded by Windows and Linux is contained within the Microchip memory disk drive file system.

When the embedded system is powered up or reset, the bootloader sub-application is invoked. If the bootloader application does not receive a command to load a new application, control is passed to the currently loaded application. We must take into consideration that the bootloader may be invoked from the application that has control and include code to cover that situation, as well.

The good news is that we don't have to scratch write a MicroSD card bootloader. The PIC18F Starter Kit is loaded with a MicroSD card socket and comes preprogrammed with a bootloader. In that the MicroSD card bootloader was written for the PIC18F Starter Kit's PIC18F46J50, OLED display, and BMA150 accelerometer, we'll cut through the underbrush and expose only the elements of the bootloader that are pertinent to a general-purpose design.

The first thing that most PIC applications do is initialize the hardware. There is no exception in the bootloader application as it calls an initialization routine right off the bat following the entry into the application's *main* function:

```
/* Initialize the boot loader IO */
BLIO_InitializeIO();
```

The PIC's SPI portal is initialized and the analog-to-digital lines are configured depending on the needs of the application. By the way, the MicroSD card communicates with the PIC18F46J50 via a SPI connection. So, initializing the SPI portal as quickly as possible is very important.

Following the initialization sequences, the bootloader sub-application begins a timed wait to determine if it needs to load a new image from the MicroSD card or simply restart the application that is currently blown into program Flash:

```
while (i < 300000)
{
    /* Check to see if the user requested
    /* loading of a new application */
    if (BLIO_LoaderEnabled() == TRUE)
    {
        BLIO_ReportBootStatus(BL_LOADING, "BL: Loading
        new application image\r\n");
    }
}
```

In the case of the PIC18F Starter Kit, the user depresses a pushbutton which is tied to a PIC18F46J50 I/O pin to force BLIO_LoaderEnabled() to return a Boolean TRUE. A adhoc software debounce routine is executed which falls into the meat of the bootloader sub-application if the debounce code is navigated successfully:

```
LoadApplication();
```

It's very difficult to load a new image if the media that

houses the new image is nonexistent. So, the *LoadApplication* function performs a test in an attempt to detect the boot medium:

```
#define BLMedia_MediumAttached()
MDD_MediaDetect()
void LoadApplication ( void )
{
    BOOL      LoadingApplication      = TRUE;

    BOOL      BootMediumAttached      = FALSE;
    BOOL      BootMediumInitialized   = FALSE;

    BOOL      BootImageFileFound      = FALSE;
    BOOL      BootImageFileError      = FALSE;
```

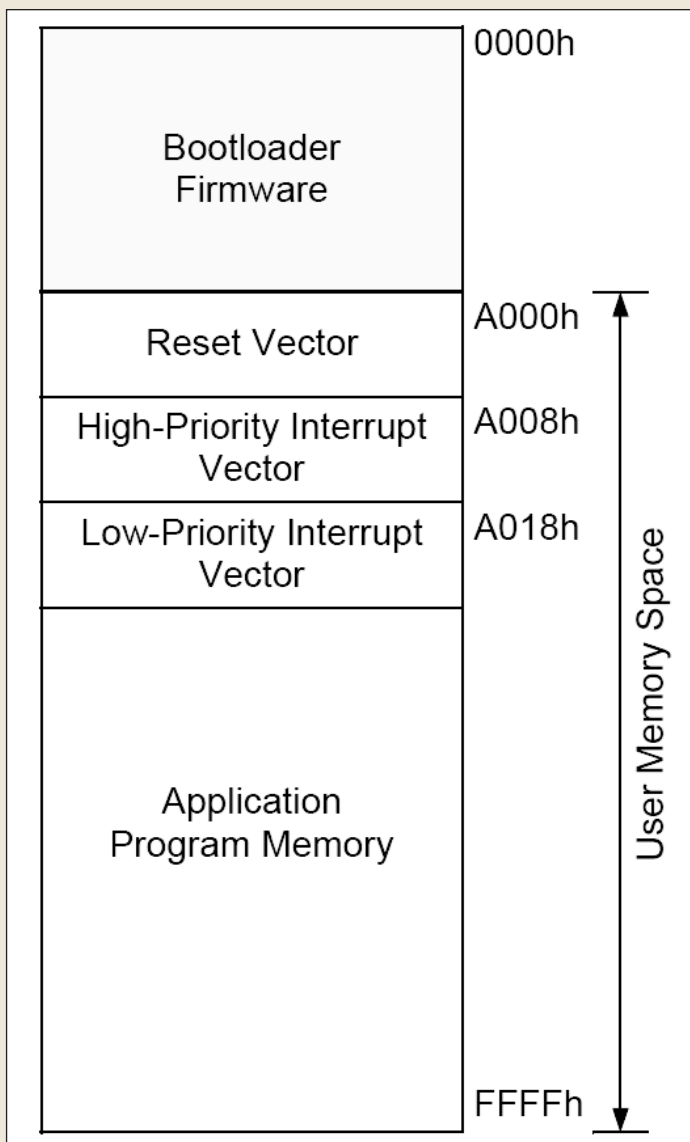


FIGURE 1. A picture is worth a thousand bytes.

```
/* Loader main loop */
while (LoadingApplication)
{
    // Check for the boot medium to attach
    BootMediumAttached = BLMedia_MediumAttached();
```

The *BLMedia_MediumAttached* call ultimately taps the SPI physical layer service that kicks off the *MDD_MediaDetect* macro which determines if a card is mounted in the MicroSD card socket. If a card is detected, the next step in the bootloader process is to verify that the media is initialized:

```
if (BootMediumAttached)
{
    /* The boot media is attached; check if
    /* it is also initialized */
    if (BootMediumInitialized)
    {
        /* Media attached and initialized */
```

Following the media verification, the bootloader code falls into a three-element state machine which will ultimately select the hex file image to load:

```
#define FILE_FETCH          0
#define SCREEN_UPDATE      1
#define USER_INPUT         2

BootImageFileError = FALSE;
state = FILE_FETCH;

while (BootImageFileError == FALSE)
{
    switch (state)
    {
        case FILE_FETCH:
            {
```

The bootloader code searches the MicroSD card and filters out the .hex files. If no files are found, a Boolean flag is set to indicate the error. Otherwise, the files are tallied and the OLED display is updated:

```
if (filesCounter != 0)
{
    /* At least one file or folder was found */
    state = SCREEN_UPDATE;
    lineSelect = 0;
    lineOffset = 0;
}
else
{
    BootImageFileError = TRUE;
}
```

The *USER_INPUT* state is responsible for guiding the user through the bootloader file selection and load process. The PIC18F Starter Kit utilizes mTouch technology to place a touch slider and two touch pads on the printed circuit board (PCB). The user navigates the directory structure and selects items displayed on the OLED display using a

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MicroSD Card Socket
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Microchip
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Libraries
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Sources

combination of the pushbutton, touch slider, and touch pads. Depending on the user input, the bootloader code will bounce around in the *LoadApplication* state machine until a .hex file is selected. With a valid application file in its grips, the bootloader disables the bootloader hardware configuration and passes control to the newly loaded application image:

```
/* Launch the application if the image in
/*Flash is valid */
if (BL_ApplicationIsValid())
{
    /* Must deinitialize the boot loader IO */
    BLIO_DeinitializeIO();
    /* Launch the application */
    BootApplication();
}
```

Naturally, there is safety net code that informs the user and programmer if the bootloader code or bootloader process falls out of bounds. Speaking of bounds, **Figure 1** puts all of the bootloader versus application memory space ruckus to rest. Here's the code behind **Figure 1**:

```
// These macros define the maximum size
// of a Flash block.
#define PROGRAM_FLASH_BASE 0x0000A000
    // Physical address
#define PROGRAM_FLASH_END 0x0000FC00
    // End of flash
#define FLASH_BLOCK_SIZE (0x400)
    // Size in bytes
```

Basically, the bootloader sub-application lives in the program Flash area below 0xA000. The interrupt vectors that the PIC18F46J50 is expecting to be available at their normal memory locations are now the property of the bootloader. So, it seems that some ISR (Interrupt Service Routine) detour code is in our future:

```
#define APPLICATION_ADDRESS 0xA000
#define APPLICATION_HIGH_ISR 0xA008
#define APPLICATION_LOW_ISR 0xA018

#pragma code High_ISR = 0x08
void Remapped_High_ISR (void)
{
    _asm goto APPLICATION_HIGH_ISR _endasm
}

#pragma code Low_ISR = 0x18
void Remapped_Low_ISR (void)
```

```
{
    _asm goto APPLICATION_LOW_ISR _endasm
}
```

We took a riverboat tour of the PIC18F Starter Kit MicroSD card bootloader code. All we were able to see were the animals that lined the shore. The wildlife behind the bootloader shore animals roams in the Microchip memory disk drive file system forest.

The Microchip Memory Disk Drive File System

The memory disk drive file system is included in the Microchip Application Libraries download. Like the TCP/IP Stack — which is also a part of the Microchip Application Libraries download — the memory disk drive file system is an API-based collection of C routines that take all of the pain out of working with a MicroSD card.

Some time ago, I designed a little ditty called the ATA hard drive controller that communicated with surplus low capacity five volt laptop drives. I recall having to write the hard drive API from scratch. The memory disk drive file system is ready to roll and can read, write, and erase files and directories on a tiny 2 GB MicroSD card.

Invoking *FSInit* initializes the memory disk drive file system library. Once the library is initialized, we can create a file like this:

```
FSFILE * pointer;

// Create a file
pointer = FSfopenpgm ("FILE1.TXT", "w");
```

The *FSfopenpgm* function will copy the file name and mode argument (w) into RAM arrays, and then pass those arrays to the *FSfopen* function. A new *FSFILE* object will be created. In this case, the new instance of *FSFILE* is called *pointer*. *FSFILE* is really a structure type that holds all of the important information concerning the open file it represents. This is what the *FSFILE* type looks like from a code point of view:

```
typedef struct {
    DISK * dsk;           //pointer to a disk
                          //structure
    DWORD cluster;        //first cluster of the file
    DWORD ccls;           //current cluster of the
                          //file
    WORD sec;             //current sector in current
                          //cluster
    WORD pos;             //position in the current
                          //sector
    DWORD seek;           //absolute position in
                          //the file
    DWORD size;           //size of the file
    FILEFLAGS flags;      //a structure containing
                          //file flags
```

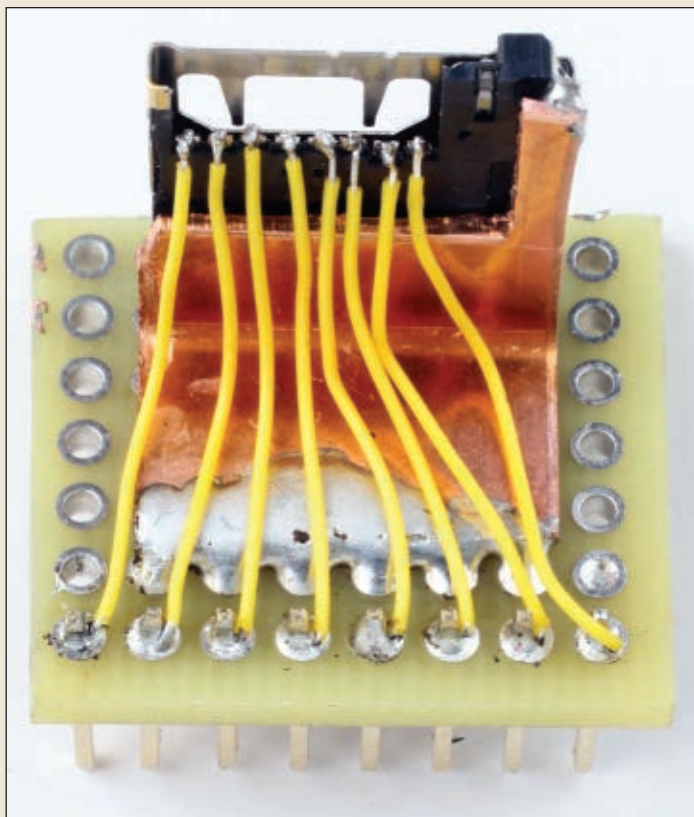


PHOTO 1. It may be ugly, but it works. You can have one of these too. Just specify Mouser part number 517-2908-05WB-MG and get out that fine-tipped soldering iron.

Now that we have an open file that we can write to, let's put something in it:

```
char sendBuffer[14] = "SERVO Magazine";
// Write 14 1-byte objects from sendBuffer
// into the file
FSfwrite ((void *)sendBuffer, 1, 14, pointer);
```

We're done writing to the file. So, let's close it:

```
// Close the file
FSfclose (pointer);
```

That file we just created and loaded with data would be useless if we couldn't read it:

```
char receiveBuffer[50];
// Open file in read mode
pointer = FSfopenpgm ("FILE1.TXT", "r");
```

Let's only read five characters from our file:

```
// Read five bytes only
FSfread (receiveBuffer, 5, 1, pointer);
```

Our *receiveBuffer* now contains "SERVO." We know that we have not reached the end of the file as "Magazine" still remains to be read. There will be times when it is important to know if the end of file position has been reached. We can easily determine if the end of file has been reached using this memory disk drive file system API call:

```
if (FSfeof (pointer))
{
    //we are at end of file
}
```

This file system can also manipulate directories just as easily as it handles files. You can get the full monty on its

file system API calls by downloading the Application Libraries package and accessing the Windows Help files, which are part of the download package. The Application Libraries download also includes example code to assist you in writing your own

```
WORD time;           //last update time
WORD date;           //last update date
char name[FILE_NAME_SIZE]; //file name
WORD entry;          //position of file's
                    //directory entry
WORD chk;            //file structure checksum
WORD attributes;     //file attributes
DWORD dirclus;       //base cluster of the
                    //file's directory
DWORD dircls;        //current cluster of the
                    //file's directory
} FSFILE;
```

The *FSFopen* function will open the file FILE1.TXT in write mode. If the file exists at the time of this open call, the existing file will be erased and a new file created.

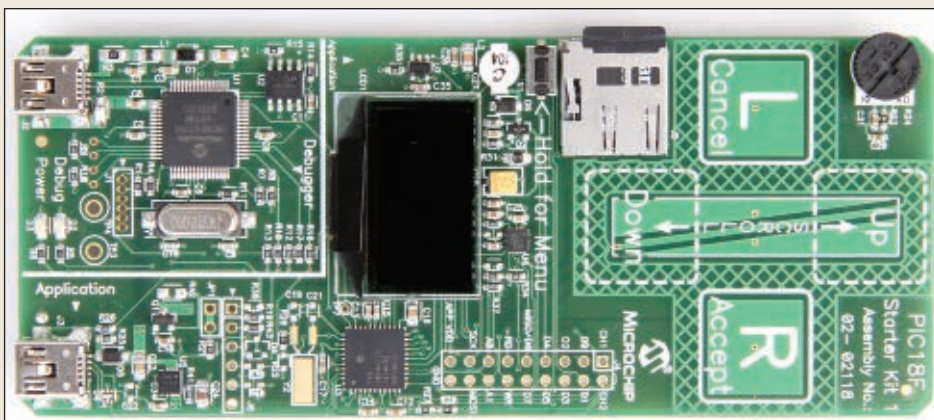


PHOTO 2. I suggest getting one of these if you want to get a feel of the OLED display and the MicroSD card without having to solder and write code.

MicroSD card applications.

What About the Hardware?

The memory disk drive file system just about guarantees success on the firmware side. However, those SMT MicroSD card sockets are tiny. A custom PCB is out of the question as you guys and gals are always telling me that some of my projects spend too much of your money. So, my goal is to implement a 3M MicroSD card socket on a standard through-hole 0.1 inch perfboard. With the help of a nibbling tool and some copper sheeting, I've done just that. The socket module in **Photo 1** supports a MicroSD card socket and provides a 0.1 inch pinned interface.

The second hurdle is the PIC18F46J50. It is not available in a 40-pin DIP package but it can be had as a PICtail. I think I'll opt to use another PIC18F part that is

offered as a 40-pin DIP. The downside is that I'll have to customize the memory disk drive file system configuration files to match the PIC I ultimately select, but flexibility is the whole idea behind the MicroSD card library structure. So, that won't be too tough of a job.

The Possibilities

I see a data logger application in our future. However, we've got to explore other microcontrollers to find out which PIC can stand in for the default PIC18F46J50 that permeates the memory disk drive file system example code.

If you're interested in how a MicroSD card works with a PIC18F46J50, get your hands on a PIC18F Starter Kit like the one you see in **Photo 2**. The upside to the Starter Kit is that you get OLED display hardware and the code to drive it. If you haven't worked with OLED displays before, they can be tricky and having a proven driver and hardware to learn from will help you port the OLED technology to your own projects. **SV**

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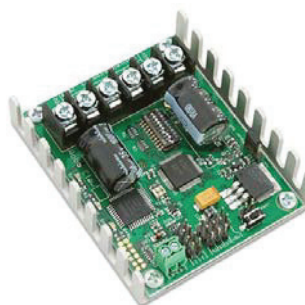
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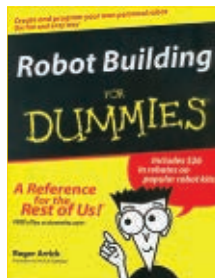
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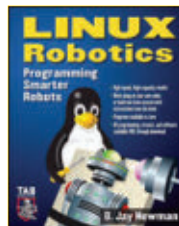


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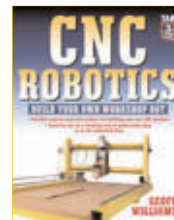
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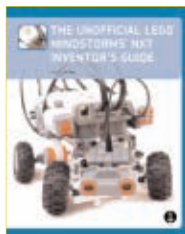
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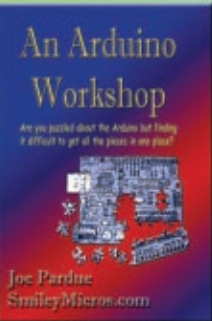
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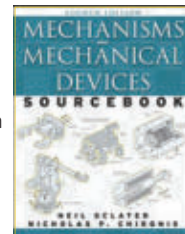


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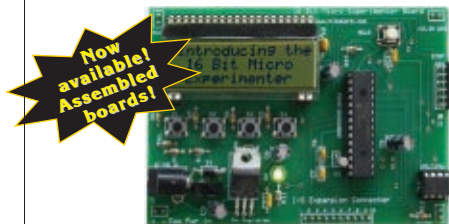
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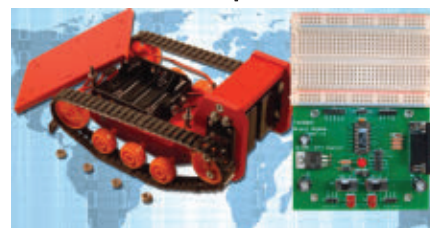
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VEX Stepper Motor Control Experiments

Part 1

The Heathkit Hero 1 was an R2D2 like robot that could be purchased for around \$1,400 in the mid 1980's. Among its many features was a voice synthesizer, an ultrasonic ranger sensor, and two light sensors. What really distinguished it from other robots available during that period, however, was its arm with a six Degree of Freedom (DOF) wrist that could pick up a coke can. This feature was normally only found in very expensive research or industrial robots. It also could move about using one large drive wheel with a heavy duty geared DC motor. It was an electro-mechanical marvel that could be assembled by anyone with basic soldering and mechanical skills if Heathkit's crystal clear instructions were followed to the letter. The Heathkit Hero 1 I helped my brother put together back in the 80's is shown in Figure 1.

Except for the main drive motor, most of the Hero 1 actuators were stepper motors of various sizes which were driven by its motor driver card which was controlled by a Motorola 6808 microcontroller. The operating system is a wonder in efficient assembly and a testimonial to the Heathkit designers. In addition, a simple language called "Robot Basic" was available that could be used to control the robot's movements and read its sensors. It used the stepper motors for its lifelike movements such as the arm, wrist, and head.

Used Hero 1 robots are sometimes found on eBay from anywhere between \$200 to \$600, depending on their condition; they make marvelous research platforms for robotics. The feature that impressed me most about the Hero 1 was the precise movements that it carried out with the arm and wrist while actually picking up an object. Unfortunately, my own Hero 1 has mechanical and electrical problems due to its age, but I plan to fix some of them using newer technologies described in this article so it will still work today despite these problems.

What does this bit of historical information have to do with VEX? Well, I have found a couple of ways to interface stepper motors to the VEX controller and adapt them to the VEX motion subsystem for use on my own stepper motor

applications — being primarily inspired by the Hero 1 robot. The Hero 1 shown in **Figure 1** has stepper motors that turn its head 360 degrees, and stepper motors to elevate its shoulder, extend its arm, and rotate its wrist 360 degrees. There's even a small stepper motor to open or close its wrist. In the VEX world, most of these functions can be done using servos and motors paired with VEX quadrature optical encoders. Using VEX motors and servos is not an option for me in this particular case because it would require far too many changes to the electrical and mechanical subsystems.

I do want to upgrade the main controller and be able to use the VEX radio control features for my Hero 1, however, and make as few modifications as possible to it. I have begun this task by replacing the stepper motor driver board with a VEX controller and some **SparkFun.com** stepper motor driver boards which I purchased for \$15 each. The advantages of this upgrade include using less power (making the batteries last longer) and improving motion and positioning since I can now micro-step the motors.

Someday you may want to animate a prop with repeatable movements or move your pet robot around using dead reckoning for navigation without having to use

FIGURE 1. The Hero 1 was an electro-mechanical marvel that could be assembled by anyone with basic soldering and mechanical skills. I helped my brother put this one together back in the 80's.

PID control and optical encoders for position/velocity feedback. Or, you may want to scan for objects using a sensor platform with a sonar or IR ranger mounted on it in order to get a clear map of the surroundings. What better way is there to obtain precise coverage than to use a stepper motor to drive the platform? If all these features are of interest to you, then you may want to build the two stepper motor controllers described in this article.

What is a Stepper Motor?

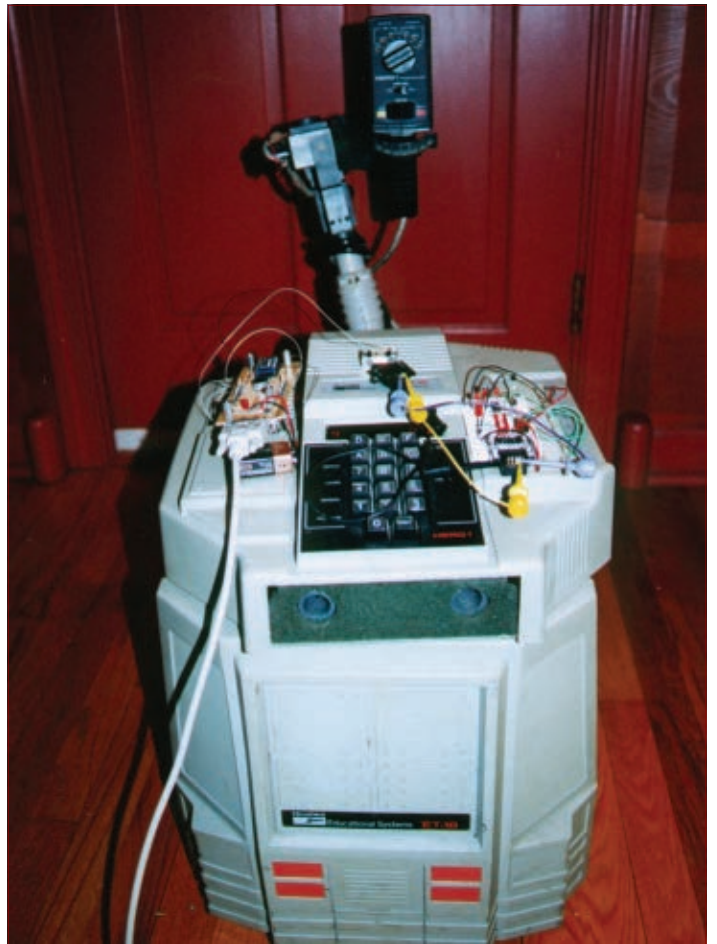
A stepper motor is a type of motor with multiple coils which moves in discrete steps instead of continuously like an AC or DC motor and need constant power to maintain their position. They are also very accurate in angular position which makes them ideal for robotics but stepper motors by their very nature are not as easy to use when compared to two-wire DC motors or three-wire servos due to the number of wires required and the special waveforms needed to energize each coil. The total number of wires needed to connect a stepper motor can be between four and eight depending on the stepper motor type, but using them for your robotics or animation projects allows you precise motion control that can drive plotters, CNC mills, X-Y-Z platforms, and tilt/pan camera platforms.

I have collected the assortment of stepper motors shown in **Figure 2** from various sources including recycling them from printers, plotters, and purchasing them from electronic surplus stores. This assortment of steppers shows the various sizes, shapes, and types (bipolar, unipolar, etc.). The standard stepping resolution for most common stepper motors is 200 steps for 360 degrees of motion or 1.8 degrees per step. Using half stepping, the resolution is doubled to 400 steps for 360 degrees or 0.9 degrees per step. Some motors can even be micro-stepped to obtain thousands of steps per revolution. For most hobbyists, this level of precision is not necessary so half stepping at 1.8 degrees per step is the precision level covered in this article.

Stepper Motor Translator IC(s)

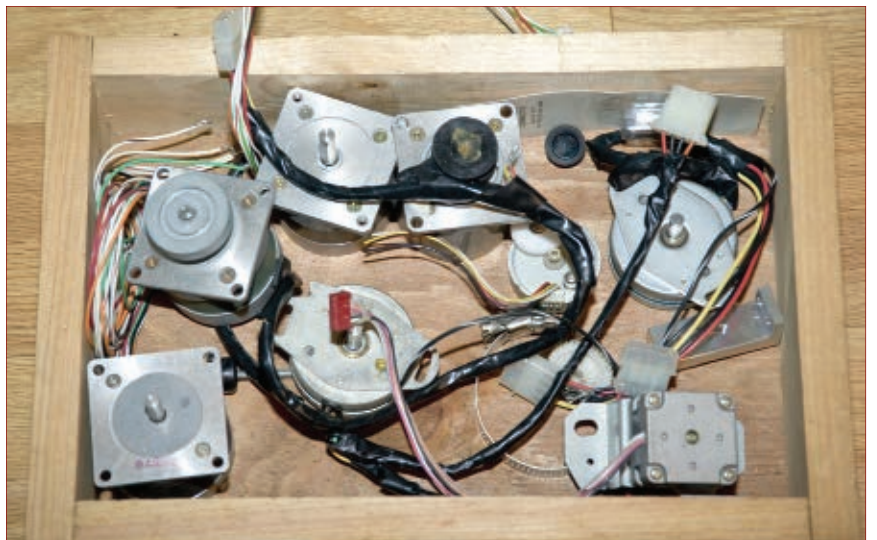
Although stepper motors are more

FIGURE 2. Here is an assortment of stepper motors that I have collected over the years from various sources including recycling them from printers and plotters, and purchasing them from electronic surplus stores.



complicated to control, there are standard stepper motor drivers available that simplify the process such as the ULN5804 and EDE1200 unipolar and EDE1204 bipolar drivers, along with full H-bridge circuit ICs such as the L298 that combined, provide the functionality of a complete stepper motor driver board similar to commercial offerings.

While this stepper motor controller design does not support high-end features such as motion control and motion profiles, it does have the following features



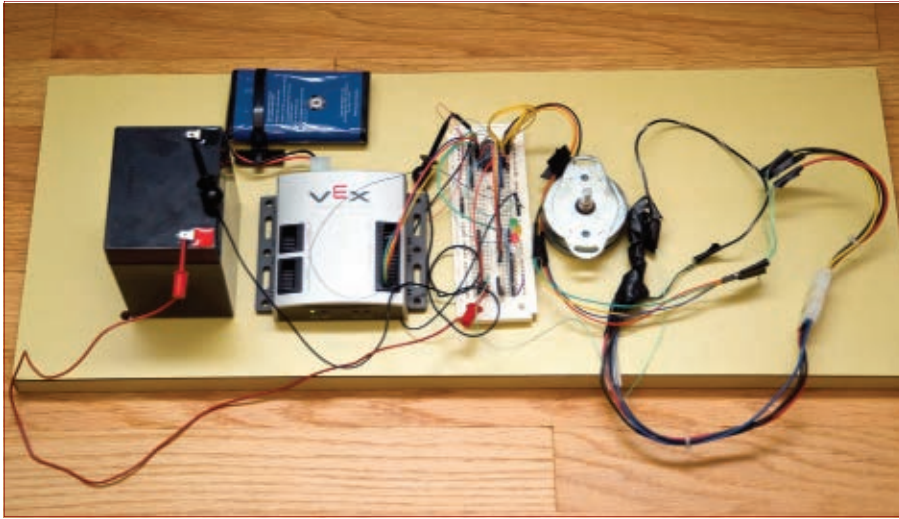


FIGURE 3. Here, we're focusing on performing basic stepper motor operations that include the full step and half step, and I also show you how to change the stepper motor direction with the simple experiment setup shown here.

including: full step, half step, and direction (clockwise, counterclockwise) which should enable you to run most common unipolar stepper motors found at places like **AlIElectronics.com** or recycled ones. Although the bipolar stepper motors provide more torque, we will use unipolar steppers for these experiments since they are easier to control.

Advanced stepper motor subjects such as PWM, chopper, L/R, current sensing, micro-stepping, motion profiles, and complex motion control are beyond the scope of this article and will not be covered here. They are used for very specialized applications that require expensive motion control hardware. Applications for these advanced features include X-Y-Z platforms for electron microscopes, high precision pick and place robots, for example.

What are the advantages to using stepper motors vs. the standard DC motor or RC servo commonly found in robotics? Well, the main advantages are precise angular positioning and stepper motor "open loop" position control. By open loop I mean that no position feedback is necessary in most situations using stepper motors. Feedback for a motor or other kind of actuator is usually provided by some kind of sensor such as an optical encoder, rotary encoder, contact sensor, or micro-switch. Disadvantages are that stepper motors have less torque for their size and are much slower when compared to standard DC motors.

Using the ULN2803A Driver IC

We will focus on performing the basic stepper motor operations that include the full step and half step modes, and I'll also show you how to change the stepper motor direction with the simple experiment setup shown in **Figure 3**. In addition, I'll show you how you can use the same circuits to drive other important actuators commonly used in robotics including relays, solenoids, and even standard DC motors, and even driving bright white LEDs or IR LEDs.

The main component of this circuit is the ULN2803A which is a high-voltage, high-current Darlington transistor array IC that replaces a handful of discrete components and

lowers the cost. The datasheet for the ULN2803A (which is located on the web at www.sparkfun.com/datasheets/IC/uln2803a.pdf) shows you that it has eight inputs and eight analog output drivers, each capable of 500 mA that are perfect for driving small stepper motors, small DC motors, relays, and solenoids all under the control of the VEX

microcontroller. In addition, you get the added protection of its internal snubbing diodes that prevent high voltage spikes generated by back EMF from collapsing magnetic fields from the stepper motor or relay coils. It also simplifies building the circuit using SparkFun jumper cables and a RadioShack white prototyping board (as shown in **Figure 3**). It is recommended that you use a buffer or driver with the VEX microcontroller output.

Fun with Steppers

The best way to learn about stepper motors is to build a simple driver circuit and use your VEX microcontroller to send them commands using Easy C or PIC18 C. A stepper motor circuit could be made from discrete components including high power transistors; these types of circuits are described in great detail in Gordon McComb and Myke Predko's book, *Robot Builder's Bonanza* [1] which I highly recommend. This book also provides an excellent description of stepper motors in general, and how they are decoded and connected. It also covers various stepper motor driving circuits that use discrete parts.

For smaller stepper motors, we can simplify things a bit and reduce the number of connections by wiring the ULN2803A based stepper motor driver circuit shown in **Figure 4** and carefully connecting it to the VEX microcontroller digital output pins on the I/O block shown in the **schematic**.

In this experiment, a ULN2803A IC is used which reduces the parts count and makes it easier to build stepper motor control using the VEX microcontroller and a low cost prototyping board. It can be purchased for around \$2 from SparkFun which is much less than purchasing the discrete components. It works well with small stepper motors, standard relays, and solenoids. For driving larger stepper motors, a board made with discrete high power transistors or HEXFETs can be more economical.

Each output from the ULN2803A is capable of driving up to 500 mA of current, but you can also pair the outputs to get four outputs each capable of driving one amp or current for driving larger actuators. A single ULN2803A can supply enough current to drive eight or more IR LEDs for a

ANALOG/DIGITAL

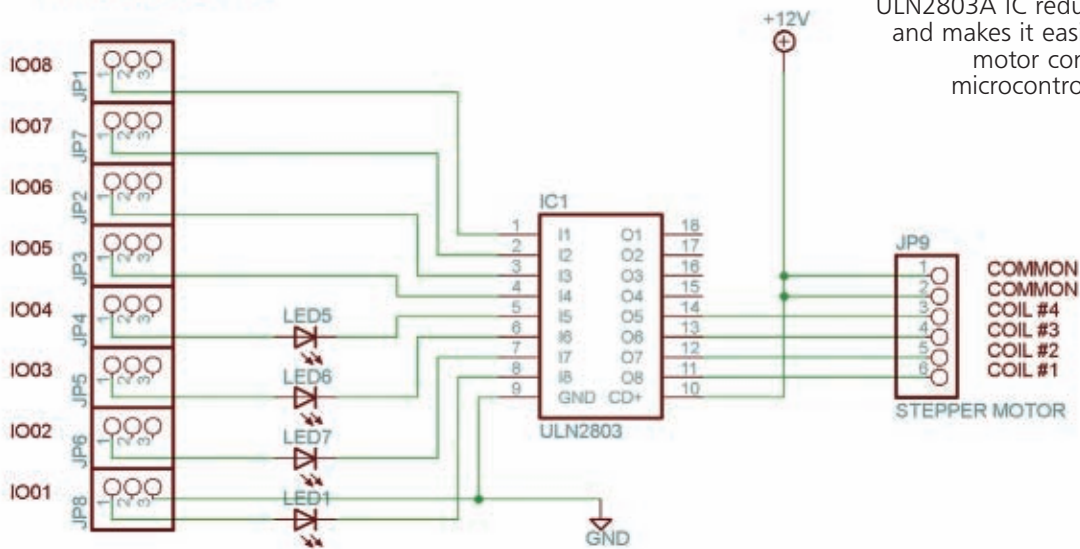


FIGURE 4. In this experiment, the ULN2803A IC reduces the part count and makes it easier to build stepper motor control using the VEX microcontroller and a low cost prototyping board.

night vision application, or it can drive up to eight relays for your next VEX animatronic prop. You can see how useful this IC is.

The circuit uses the ULN2803A to drive small stepper motors; it can also be used to drive relays and solenoids. It works with the VEX microcontroller and the Easy C professional application to energize each coil in a specific sequence depending on the stepper motor controller mode being used. The four LEDs shown in the **figure** are optional, but very useful to determine if the circuit is working. Each LED corresponds to one of the stepper motor outputs and should light up when activated. Pay particular attention to the power and ground wires, making sure there are not shorts and that all the jumper wires are inserted in the correct locations on the prototype board and controller. I used the SparkFun jumper cable kit to build the circuit shown in **Figure 4**; you can use wire-wrap or point-to-point wiring to build the same circuit and get the same results. This latter construction method is recommended if you intend on using the circuit for driving a robot or mechatronic assembly.

Do not power the stepper motor circuit directly from the microcontroller. Instead, use a separate 12 volt rechargeable SLA battery, or even a 9.4 volt VEX rechargeable battery or 12 volt bench power supply. Remember to connect the ground wire between the (-) terminal of the 12 volt power supply and the Vss pin of the ULN2803A IC. The stepper motor driver circuit should not be powered until the stepper motor has been connected. Stepper motors are power hungry devices, so make sure that the batteries are fully charged before attempting to power the circuit. Also, use a switch or jumper cable for disconnecting the power to the stepper motor when not in use.

This circuit is capable of driving a small to medium sized unipolar stepper motors. Once the circuit has been assembled and tested, it is time to connect the stepper motor to the circuit.

Connecting the Stepper Motor

Unless you are lucky enough to find a stepper motor with a wiring diagram, there is a bit of detective work we need to carry out in order to determine how the stepper motor should be wired to the stepper motor driving circuit. The tool required for this task is a digital voltmeter, and we'll use it to measure the resistance between each of the wires.

Caution: Be sure to wear your safety goggles while working with the power supply and running the stepper motor. Never connect the stepper motor directly to the microcontroller or you risk damaging it. Also, disconnect power to the motor when working on the circuit to avoid short circuits. If the wires start getting warm or hot, disconnect the power immediately.

Without getting too technical, the differences between unipolar and bipolar stepper motors usually refer to the number of windings and phases required. A unipolar stepper motor normally has anywhere from five to eight wires, and a bipolar stepper motor has four wires. We will be using a unipolar stepper motor for this experiment and it will require some initial preparation using a DVM (digital voltmeter) to decode the wires before connecting them to the stepper motor controller. This stepper motor is easier to drive since there is no current reversal required. This is the most common type of stepper motor.

Another method for decoding stepper motor wires — which works well for me but can take a little longer — is the trial and error method. Start by using a stepper motor with more than four wires leading from it (since four wire steppers are usually bipolar and can't be used for this experiment). I found that it is convenient to connect .100 pin headers to the stepper motor wires so that the jumper wires can be used for the motor connections to the stepper motor circuit. This way, they can easily be swapped if necessary when making the connections.

Using the DVM, find the pairs of wires that have similar resistance and label them P1 and P2. These are the four control wires. Also find the pair of wires that do not measure any resistance and label them the positive power source Vcc (+12 volts). Do not connect them to the battery or bench power supply at this time. The ground (Vss) wire leading from the stepper motor controller circuit should already be connected to the (-) terminal of the 12 volt battery as shown in the **schematic**. Make sure that the ground wire is connected between the stepper motor controller circuit and the microcontroller. Use the DVM to insure that there is continuity between all these power and ground connections.

Start the wire decoding process by downloading and running the Easy C Professional Stepper Motor application stepper1.hex that is provided on the *SERVO* website at www.servomagazine.com. The LEDs should be flashing in a specific pattern indicating that the stepper motor coils are driven using the full step or wave step pattern. Take the remaining two pairs of wires leading from the stepper motor and connect them to the stepper motor driving circuit as shown in the **schematic**. Now connect the (+) terminal of the 12 volt battery or bench power supply to the pair of wires labeled +12 volts and watch carefully for any shorts or hot wires. See if the stepper motor starts turning or vibrating. If it turns CW or CCW, congratulations! You are done. Otherwise, repeat the above procedure, but swap the positions of two pairs of control wires, P1 and P2 and even swap the wires between each pair until the stepper motor starts turning. Make sure that you remove the +12 volt power cable while performing the swaps. If the stepper motor starts to move in both directions, it means you are getting closer to the correct connection. If this process does not seem to work for you, it could be that you are trying to connect to a bipolar stepper motor or that the stepper motor requires higher voltage and current (some stepper motors use 35 volts).

Using a driver such as the ULN2803A for driving stepper motors is a good way to learn how they work. It also protects the microcontroller from possible harm from

voltage spikes induced by the stepper motor coils from currents induced by collapsing magnetic fields “snubbing out the spikes” with its internal protection diodes. Using it for driving large stepper motors is not recommended since they can draw much more than the 500 mA from each coil.

A more efficient approach is to use a dedicated stepper motor controller IC — also known as a stepper translator IC — which is designed to activate and provide each coil winding inside the stepper motor with the maximum current possible while protecting the microcontroller inputs with its internal diodes. In addition, it generates the required full step or half step or wave coil activation waveforms.

VEX Control of a Stepper Motor

To illustrate how to use stepper motors with the VEX microcontroller in action, I'll show you how to use it to drive a low cost stepper motor purchased from a surplus electronics store.

Using stepper motors on a VEX controller is a little more involved than using the standard VEX motors and servos which just plug and play using Easy C Professional. Simple control (single step and half step) of stepper motors can be accomplished using just four of the controller's digital outputs and some discrete components. The disadvantage of this method is that this stepper motor driver circuit is not very efficient and it requires four digital outputs per stepper motor. In addition, the controller requires fast recovery diodes to protect the digital outputs from back EMF. There are many factors that go into controlling stepper motors. These factors include being able to change the speed, position, stepper motor type (unipolar vs. bipolar), step mode (full, half, single, back), direction, current sensing, clocking, braking, micro-stepping, and ramping profiles.

Changing the stepper motor speed or acceleration is not as simple as changing it on an RC servo such as the VEX motor or VEX servo or even a DC motor. Discreet

```
#include "Main.h"
void main ( void )
{
    int i = 0; // Loop Index for VEX Output Bit
    int j = 0; // Loop Index for Stepper Motor Command

    // Single Phase Stepper Motor Commands
    int Single_Phase[4] = {0b0001, 0b0010, 0b0100, 0b1000};

    // Dual Phase Stepper Motor Commands
    int Dual_Phase[4] = {0b0011, 0b0110, 0b1100, 0b1001};

    SetDigitalOutput ( 1 , 0 ) ; // Turn Coil 1 Off
    SetDigitalOutput ( 2 , 0 ) ; // Turn Coil 2 Off
    SetDigitalOutput ( 3 , 0 ) ; // Turn Coil 3 Off
    SetDigitalOutput ( 4 , 0 ) ; // Turn Coil 4 Off

    while ( 1 ) // Stepper Motor Control loop
    {
        // Loop for Stepper Motor Commands
        for ( j=0 ; j<4 ; j++ )
        {
            // Loop for activating each coil
            // from the Stepper Motor
            // using the Single Phase bit patterns
            for ( i=1 ; i<5 ; i++ )
            {
                // Turn Coil On or Off
                // depending on stepper
                // motor command
                SetDigitalOutput ( i , (Single_Phase[j]>> (i-1)) ) ;
            }
            // Wait 7 milliseconds - works
            // with larger six wire
            // stepper motor and a ULN2804 IC
            Wait ( 7 ) ;
        }
    }
}
```

LISTING 1. This is an example written in Easy C Professional that shows you how to move the stepper motor using the full step mode with a microcontroller and a ULN2803A driver.

speed changes are accomplished via a timer interrupt or loop with delays between steps. This is where controlling stepper motors can get more involved than other types of motors. They have an advantage when used for position control and open loop control but require the use of a timer interrupt using an interrupt service routine (ISR) or a delay.

Newer stepper motor drivers such as the EDE1200 and the SparkFun Easy Stepper board provide the necessary timing for waveform generation. The EDE1200 even provides a clock using an external crystal to drive the stepper motor at various speed increments. On the microcontroller, we have the ability to generate delays using the Easy C Professional or PIC18 C Wait(n) functions, where n is the number of milliseconds to delay.

VEX Stepper Motor Controller Firmware

In order to make the stepper motor move at the selected speed and in the desired direction (clockwise or counterclockwise), you just download and run the stepper1.hex application on the microcontroller using the Intellitek Easy C professional or IFI bootloader application.

Listing 1 shows the details of how the stepper motor is driven to run in half step and full step modes in the selected direction. I used Easy C Professional for the example in **Listing 1** which shows you how to move the stepper motor using the full step mode with a microcontroller and a ULN2803A driver.

We also provide the hex file for those readers who do not use Easy C Professional. This example is very easy to port to Easy C, Robot C, and PIC18 C with WPILIB. The simple stepper motor command messages are formatted and sent to the controller so that it can move the stepper motor the selected number of steps in the desired direction. To make the stepper motor move in the reverse direction, just reverse the direction of the outer stepper motor command loop by modifying the stepper1.c application. The complete source code is available for download from the *SERVO* website download page.

Bill of Materials

The parts required to build the VEX user interface circuit are shown in **Table 1**. Other than the microcontroller, the other components are relatively low cost and can be found at All Electronics or SparkFun. The jumper cables make it very easy to connect the stepper motor to the VEX controller but should only be used for the experiment since they can easily

TABLE 1. Bill of materials required to build the stepper motor experiment setup.

ITEM	QTY	DESCRIPTION	SOURCE
1	1	VEX Controller	Innovation First, Inc. www.vexforum.com
2	1	White Breadboard	RadioShack www.radioshack.com
3	1	ULN2803A	SparkFun www.sparkfun.com
4	4	LEDs	RadioShack www.radioshack.com
5	1	Package of Jumper Cables	SparkFun www.sparkfun.com
6	1	Stepper Motor Bipolar (six wire)	All Electronics www.allelectronics.com

pull out of the controller.

Conclusion

Using simple hardware with some firmware, precise and repeatable movement is possible for your next robotics or automation project using the information that I provided here. Stepper motors need not remain a mystery to use if you build the stepper motor controller. In addition, you will learn just how stepper motor based devices such as printers, plotters, and scanners work. The Hero 1, on the other hand, demonstrates how very complicated animation sequences (such as picking up a can of soda) can be carried out using stepper motors.

This controller is the first step towards precise position or motion control afforded by more expensive commercial controllers. In Part 2 of this article, I will show you more applications for the ULN2803A including driving relays and solenoids, and more advanced VEX stepper motor applications. Until VEX time. **SV**

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Then and NOW

FROM GARCO TO THE NEW BOTS IN TOWN

by Tom Carroll

I've been writing about robots in SERVO Magazine and Nuts & Volts since the summer of 2003 and most of my articles have covered the historical aspects of specific robots that were state-of-the-art "Then," and what types of robots are considered "Now" with today's technology. I still receive comments about many of the old robots that I wrote about years ago and I am always asked to write about some cool robot from the past that a reader has heard about. Garco, from 1953, has been one of the most requested robots people have wanted some information about, as well as the REEM series of robots that I briefly mentioned in the May '10 issue of SERVO.

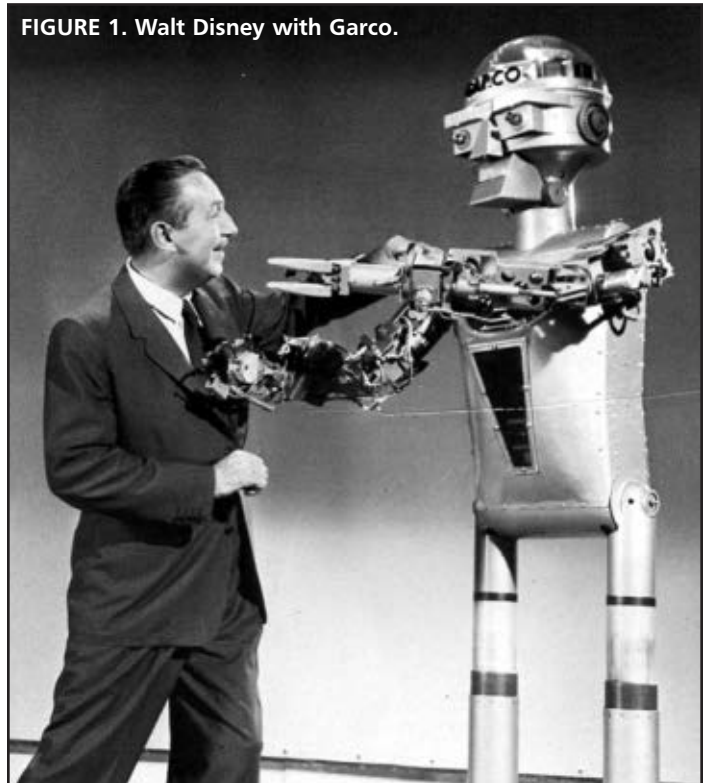
Garco — An Early Hobbyist-Built Robot

Garco made headlines around the world back in 1953, not because it could actually perform tasks that one normally thinks of as human capabilities, but because it was the only robot around in those days. **Figure 1** shows the robot with Walt Disney on a TV episode of Disney's *Tomorrow Land*. There is speculation that Garco might have influenced Disney in his later audio-animatronics installations at Disneyland. Garco was built by Harvey Chapman, Jr., at his home. He was an engineer for the Garrett Supply Company of Los Angeles and he built it not as a robot to replace human workers, but as a hobby project. He had access to many surplus aircraft parts — the ideal industry as a source for robot stuff. His home garage served as his workshop — a typical place that most robot hobbyists use for their robot construction projects (especially the larger ones that don't fit on the kitchen table).

Because it was one of a kind, Garco soon became capable of an amazing array of tasks. Media has a way of turning something that is ordinary into something amazing. I suppose that Garco seemed a bit awe-inspiring to the average person of the early 50's, but unbelievable headlines soon arose. A new science fiction motion picture, *Gog*, was soon to hit local theaters around the country and promoters felt that this robot was the ideal 'spokes robot' to advertise the film. Unfortunately for the movie people, newspapers were more interested in

the robot than the movie. "Operated by remote control, the robot can perform with his arms and hands virtually on a level with a human. Garco, who represents a million

FIGURE 1. Walt Disney with Garco.



dollars in electronic research plans a personal appearance tour of the country in behalf of the movie," was one comment made in papers.

Garrett Supply certainly did not give Chapman any money to build the robot other than his salary as an engineer. It was a side-line labor of love for this engineer and pioneer hobby robot builder. Garco's most famous photo (**Figure 2**) shows actress Sally Mansfield sitting beside him as he 'types' out a press release for Gog on a typewriter. Sally was a regular on the early CBS-TV Sci-Fi series, *Rocky Jones, Space Ranger* as Vena Ray, spaceship navigator. This was a popular television show in those days. The use of a robot to advertise the movie was a natural, as a deadly robot went out of control in the final scenes of the movie (something we all know robots can do on occasion). Showing gentle Garco as a Hollywood press agent might have added a bit of a twist to the public's conception of robots.



FIGURE 2. Garco with Sally Mansfield in 1958.



FIGURE 3. Garco staged as 'stacking boxes.'

'famous for being famous' — much like some of the celebrities that we read about these days.

Ten-year-old Terry Chapman (Harvey's son) was the hero of his neighborhood since his father had a six foot high mechanical monster out in the garage. The younger Chapman was adept at operating the robot and delighted neighbors and news people alike by making the robot do all sorts of tricks and movements. One time, someone

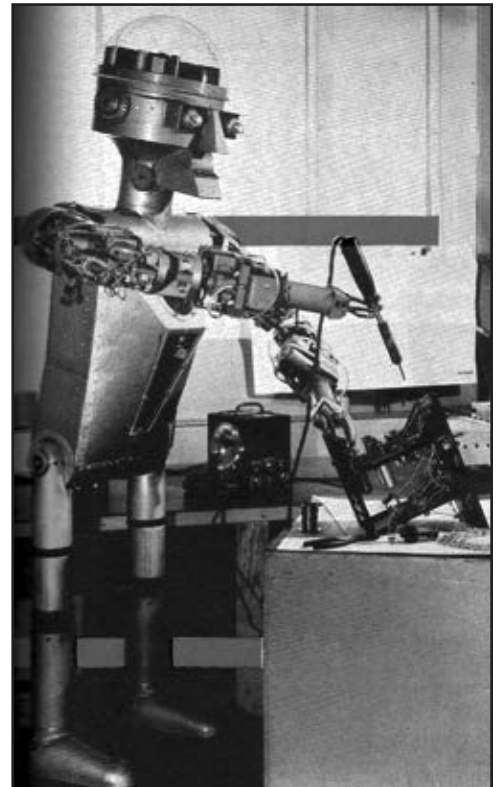
Media Hype Opens Up Uses For Garco

As I stated earlier, Garco was a talented hobbyist's part-time project that took off with the tremendous media coverage. The earliest newspaper articles of the time stated that "Garco represents one of the first attempts at an all-purpose functional humanoid robot." In reality, at first, it was more like "I have the junk parts from many old airplanes available; I have the engineering background; I'm going to build a robot in my spare time. In the beginning, Harvey Chapman enjoyed touring with the robot as a crowd-gathering attraction, much like the later promotional robots we've seen for years. Garco became

FIGURE 4. Garco as an umpire telling a player that he's out.



FIGURE 5. Garco 'soldering.'



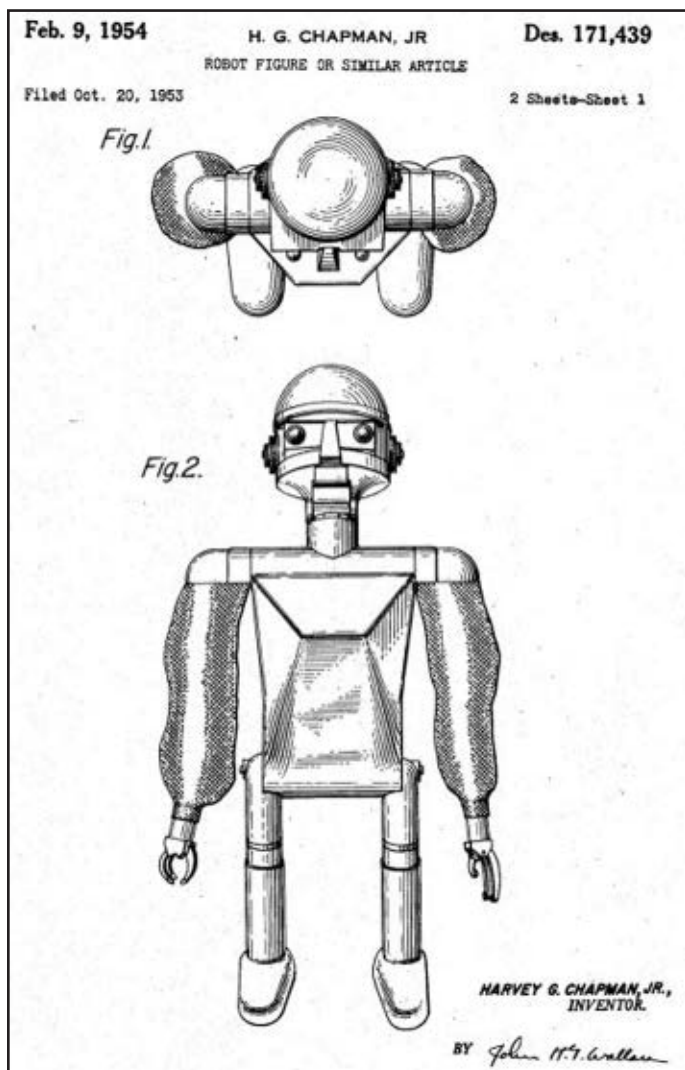


FIGURE 6. Garco patent application 1A.

accidentally pushed the 'bow' button too long and the robot toppled over and smashed his head and nose — much to young Terry's horror. Garco's only competition for headlines was Westinghouse's Elektro, the huge robot built 15 years earlier for the 1939 New York World's Fair.

As his and the robot's fame increased, Chapman began to realize that his design could have other uses such as "taking on a variety of tasks that would prove too dangerous for humans," he noted. "Mixing the ingredients for TNT is one. If the stuff should blow up, you could install another robot and continue the job without much loss. Garco could work efficiently in a vacuum; in temperatures that would burn or freeze a man; handle radioactive elements without endangering anyone; or labor for hours on end under water." The 'engineer' in Chapman saw these unique capabilities but the potential investors only saw entertainment uses. I'm sure these applications and many others influenced George Devol and Joe Engelberger a decade later when they marketed the first Unimate industrial robot.

Some of the robot's 'photo ops' that made headlines

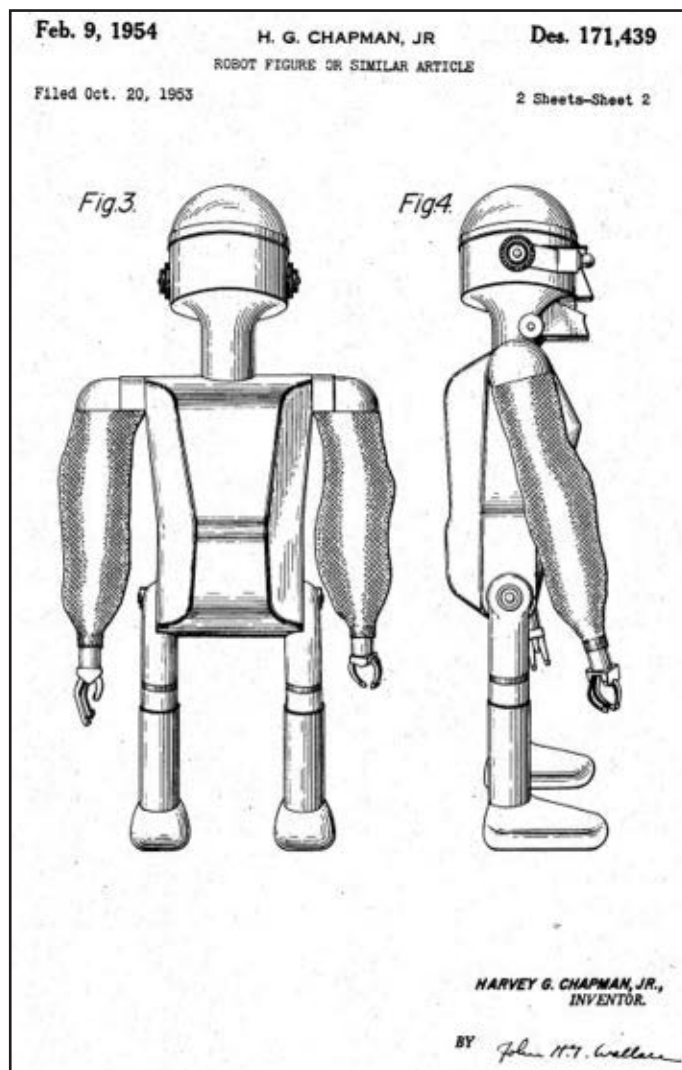


FIGURE 7. Garco patent application 1B.

in papers across the US showed Garco stacking boxes in a warehouse (**Figure 3**); acting as an umpire (**Figure 4**), and even soldering electronic circuits with one of those old giant soldering irons (**Figure 5**). Everything was all staged, of course. Joe and George first saw assembly line applications for their Unimate — especially in the automobile industry — but more applications for robots came soon afterwards that were beyond Garco's abilities. Of course, stacking boxes would be automated by robots a few decades after this and some soldering tasks have been taken over by SCARA robots for circuit board assembly (soldering irons are no longer used in favor of flow soldering).

How Was Garco Built?

Garco was not autonomous by any means but his remote control method and the arm construction was way ahead of its time. **Figures 6-11** are from two submissions for a patent on the robot by Chapman on October 20th and November 16th of 1953. **Figure 6** and **Figure 7** show

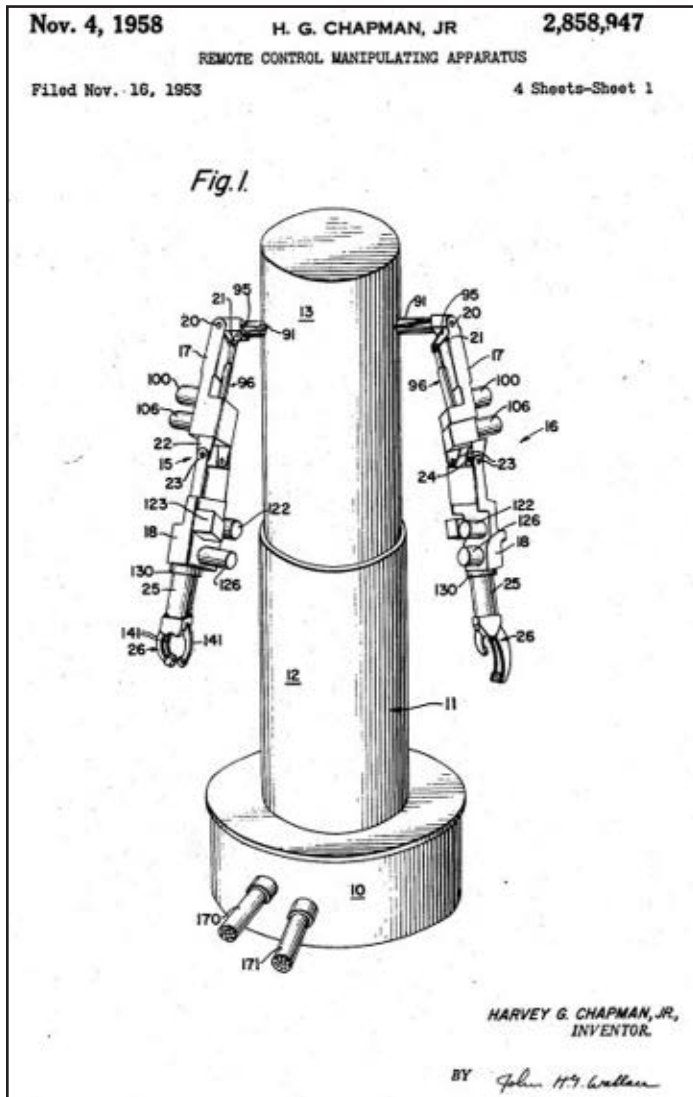


FIGURE 8. Second Garco patent application 2A.

the aesthetical views of how Chapman intended Garco to appear when completed. (This part of the patent was granted early in 1954.) Note he did not show the base that Garco was mounted on and the arm assemblies are covered with fabric or rubber.

The second set of patent drawings show more of the mechanical and electrical aspects of the robot. **Figure 8** shows a test column on which the complex 'Remote Control Manipulating Apparatus' is mounted. This part of the patent was granted almost five years later. Cables 170 and 171 at the bottom are connected to the sending unit (shown in **Figure 9**) that replicates the operator's arm movement. Pushbuttons and toggle switches enable or disable sections of the robot's arms. In **Figure 10**, a linear actuator (numbers 96 to 101) moves the arm up or down. Motor/actuator 106 moves the elbow joint and motors, while 122 and 126 rotate the wrists and open and close the claw. It appears that Chapman used dual wound field DC motors to drive the linear actuators both directions through gearboxes, as **Figure 10** seems to indicate. **Figure**

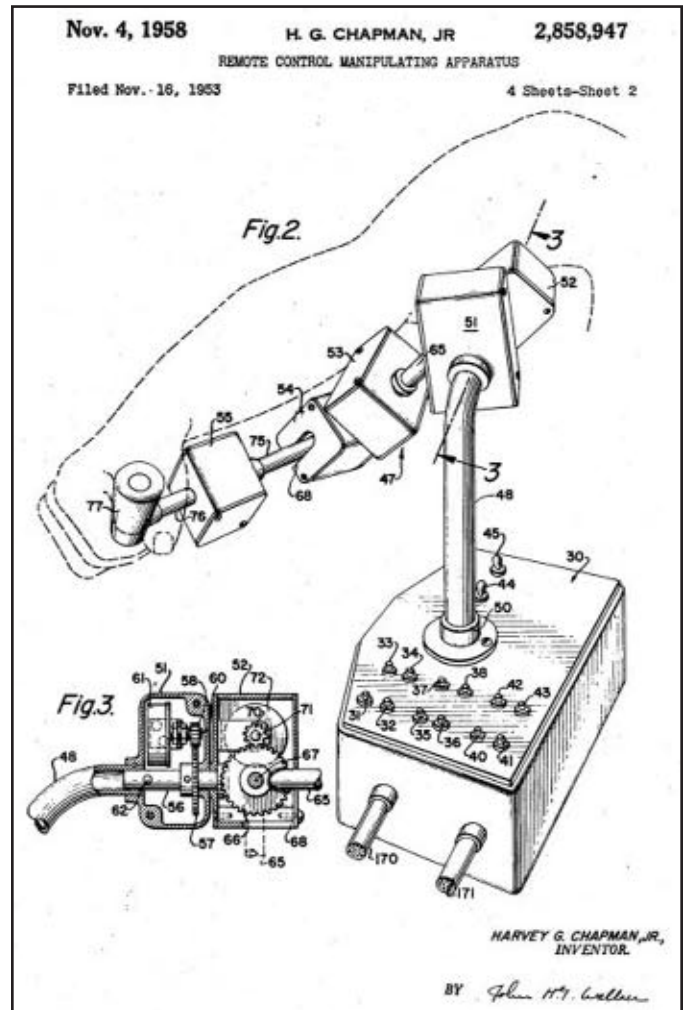


FIGURE 9. Second Garco patent application 2B.

11 shows an excellent view of the claw and actuators, as well as the shoulder actuator.

How Is Garco Controlled?

According to an article — *Plug-In Workman Built in 90 Days* — written about Garco in the December 1953 issue of *Popular Science*: "Chapman brings Garco to apparent life by first opening the circuits and sending electricity surging into the complex metal body. He then lays his right arm along a five-jointed electro-mechanical control arm which has a handgrip at the end of it. The joints can be moved up and down, in and out. As Chapman twists and turns his own arm — and the control arm along with it — Garco's right arm moves in exactly the same way. Garco is so sensitive, in fact, that if Chapman's hand shakes, Garco's does too. Garco's brain was electronic using six aircraft servo systems. His nervous system consisted of 1,200 feet of wire cable. A two-way radio transmitter enabled Garco to make pertinent remarks.

Today's definition of electronic refers to ICs, transistors, or at least tubes, but it appears that anything full of wires and motors was mysterious enough to be called 'electronic'

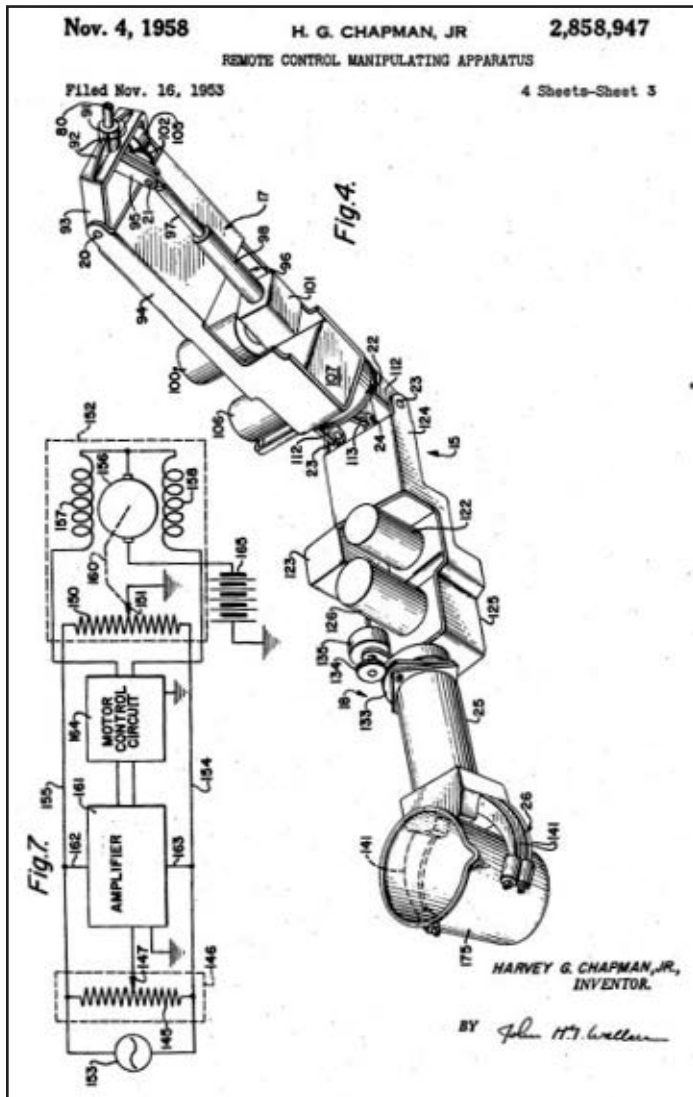


FIGURE 10. Second Garco patent application 2C.

back in 1953. There are several brief mentions I found of Chapman using synchro-selsyns as the position sensors of his control arm and as the driving motors for his arms. Synchro-selsyns were traditionally used as position indicator devices to indicate antenna, shipboard guns and mechanism positions, and are AC driven and usually don't have enough torque to move anything heavy. However, they have been geared down enough in some applications to deliver a lot of torque. In this type of application, the driving synchro must deliver even more force to overcome system gear friction. They were quite popular military surplus items several decades ago but are hard to find these days. In my research, most articles about Garco referred to DC motors to drive his arms.

Figure 9 shows how Chapman placed his arm in the 'sending unit' to control the right arm. The toggle and pushbutton switches controlled motion of the left arm. The *Popular Science* article further describes the robot's control systems. "As the joints in the control arm move through six electric channels, they notify sensing devices in Garco's

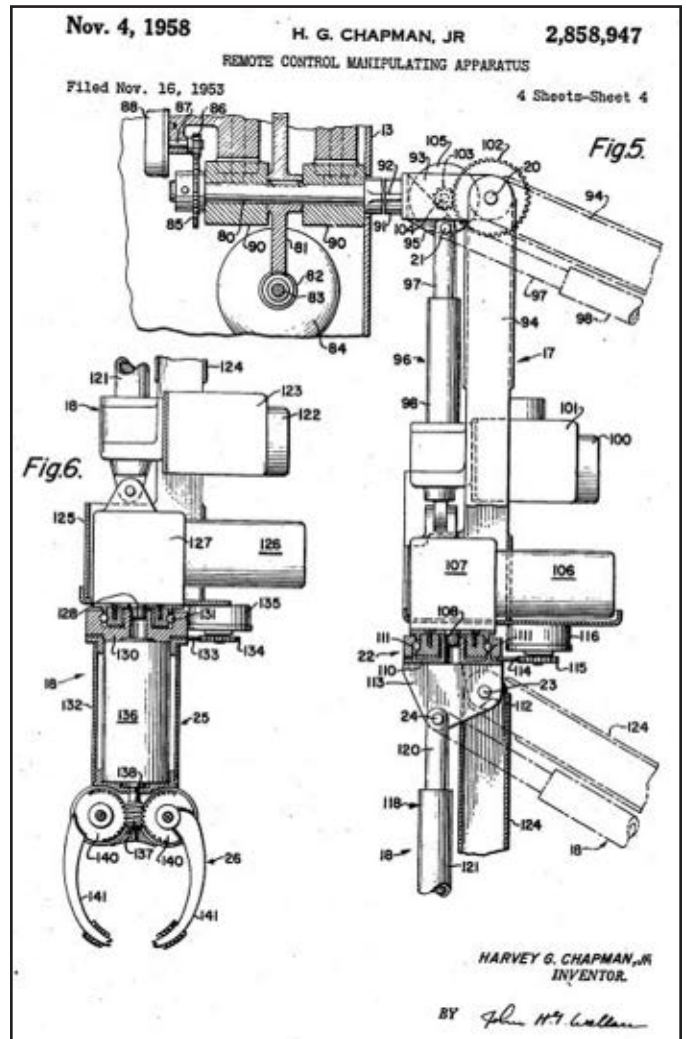


FIGURE 11. Second Garco patent application 2D.

electronic brain that they have disturbed the balance in many Wheatstone-bridge systems. The disturbance of each fires an electronic tube which, in turn, fires a relay tube which actuates one of the five .05 HP motors in Garco's right arm. So much for the right arm; Garco's left arm is manipulated by 22 pushbuttons, mounted on the case of the control arm. The pushbuttons — in addition to working Garco's left hand and arm — move the robot's jaws and lips, increase his height six inches, roll his plastic eyes, and enable him to bow at the hips."

Building Garco cost Chapman less than \$1,000 for materials ... "you couldn't buy it for several times that sum," quotes *Popular Science*. "What father," Chapman asked, "would put his own child on the auction block?" At the ripe old age of eight, Garco was pretty much worn out and faced retirement in 1961.

The New Bots In Town

Harvey G. Chapman Jr., was certainly a robot innovator for his day and age. Today — almost 60 years later — bipedal robots do not require fastening to a base for

stability as they are quite mobile, walking and balancing on two legs and feet. Some of the newest and most unique – if not most capable – bipedal robots come from two countries people usually do not think of for this type of technology: the United Arab Emirates and Vietnam. Several months ago, I mentioned an interesting robot called the REEM-B from a UAE company. It is an amazing robot and I had quite a few emails asking me more about it.

The REEM series of robots gets their name from Reem Island, or actually Al Reem Island about 600 meters off the coast of Abu Dhabi, UAE. This city is the center of explosive growth in the Middle East and many companies – both small and large – are centered there, as

well as lavish housing and entertainment facilities. The REEM robots were developed by Pal Technology based in Abu Dhabi. The company is well known for its reverse osmosis desalinization plants (a greatly-needed product in this parched part of the world) but they also are big in construction, IT, and security.

A division of Pal Technology is Pal Robotics, builders of the REEM robots. The company is situated in Barcelona, Spain and is led by an Italian, Davide Faconti, who leads the team of Italian and Spanish engineers. Their first robot (REEM-A in **Figure 12**) was built in 2006 when several other human-sized bipedal humanoids such as Asimo and Hubo were making headlines around the world. After seeing the success of their first robot, Faconti and his team

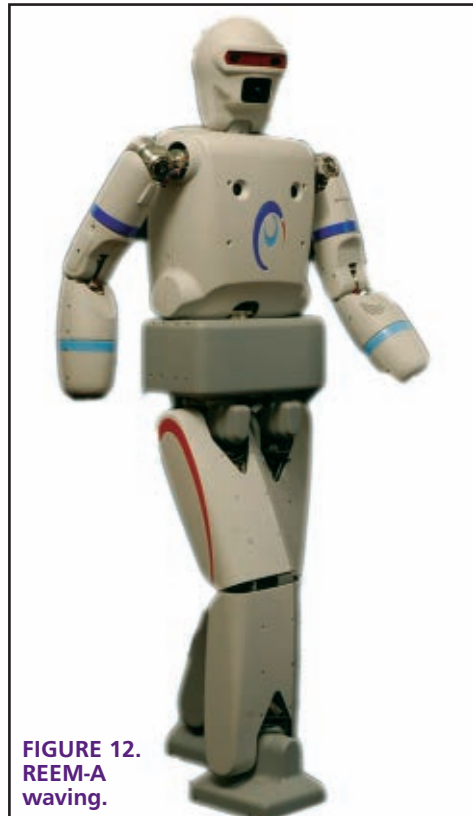


FIGURE 12.
REEM-A
waving.



FIGURE 13. The
REEM-B robot.

at Pal Robotics vastly improved their design and the REEM-B evolved (shown in **Figure 13**). The new robot debuted in June '08 and weighs 60 Kg, stands 1.47 meters high, can operate for an amazing two hours, and possesses 51 degrees of freedom in the arms, legs, and body joints. It can walk at 1.5 Km/hr, can climb stairs, and can carry a payload of 12 Kg. Obviously, to walk as a biped REEM-B needs a gyro system, as well as accelerometers feeding its

FIGURE 14. REEM-H2 robot as museum guide.



FIGURE 14.
REEM-H2 robot.



Core2 Duo processor. I have watched numerous videos of this robot over the past two years and it has some amazing walking movements as well as stability which are difficult motions to control in a large bipedal humanoid.

"REEM-B has the unique ability to map and self localize itself, both elements that distinctly set it apart from REEM-A. Although both robots can perform face recognition, object recognition, voice recognition, and walking, REEM-B can also converse with humans, walk dynamically, recognize and grasp objects, accept voice commands, and even remind appointments," quotes Faconti. "REEM-B is also able to carry up to 25% of its weight, making it the world's strongest humanoid robot. In addition, the robot has a fingered hand with 12 motors, and is able to maneuver up and down stairs, with added sensors to ensure that it avoids any obstacles.



FIGURE 15. Tosi Robotics' Topio ping pong playing robot.

"Mr. Basar Shueb, General Manager of Pal Technology said: "Pal Technology's ultimate goal is to create a truly useful humanoid service robot that will be able to help humans in the future with sophisticated tasks. REEM-B is clearly aligned with this vision, not only representing the next generation of humanoid robotics, but a robot designed to assist people and not replace them."

The Topio Robot From Tosi Robotics

A robot that has been making the rounds on YouTube and other websites is the Topio robot from a Vietnamese company called Tosi.

Established in 2002, the company has a great ambition to be one of the leading brands of robots in the world, and that includes industrial, service, and toy robots. Based in Hanoi, Tosi has marketed a few industrial and toy robots, but they have showcased three successive ping pong playing robots to show the public their emerging technical expertise.

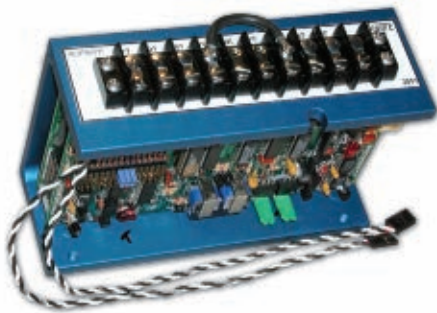
The first Topio (version 1.0) made its public debut at IREX 2007 in Tokyo, Japan. The Topio 2.0 version shown in **Figure 15** has been in the news quite a bit and has a most unique form as a humanoid. It does not walk as it is affixed to the floor, but it sports a set of cool sunglasses, a buff exterior with bulging abs and pecs, and does a fair job at beginner's ping pong. Topio 3.0 has 39 degrees of freedom, stands 1.88 m tall, and weighs 120 kg. The actions of each successive robot have been improved over the previous version but — to the observer — the movements seem, well, very robotic. The real key, here, is the vision system working in conjunction with the mechanics to track a fast moving ball.

Final Thoughts

It is quite a pleasure to see imaginative people stepping forward to design and produce some amazing robots. As we've seen, this imagination is not limited to the 'first-world' countries who, for years, have been the producers of the world's high technology products. Vietnam and the United Arab Emirates in the Middle East have taken major steps and have produced some unique products. However, garage hobbyists are still the ones designing and building robots from surplus items that match the best from industry and academia. **SV**

Tom Carroll can be reached at TWCarroll@aol.com.

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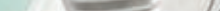
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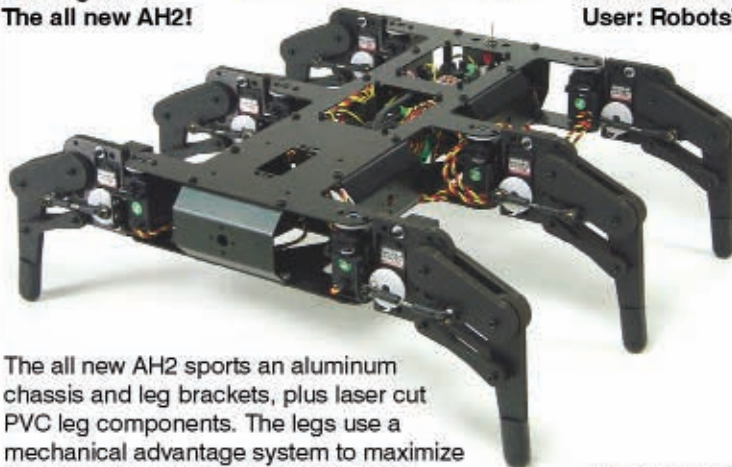


**The Lynxmotion Servo Erector Set
Imagine it... Build it... Control it!**

Featured Robot

**Coming Soon!
The all new AH2!**

**Youtube videos
User: Robots7**



The all new AH2 sports an aluminum chassis and leg brackets, plus laser cut PVC leg components. The legs use a mechanical advantage system to maximize payload even when using inexpensive servos. This is 2DOF Hexapod, done right!

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anodized finish!**



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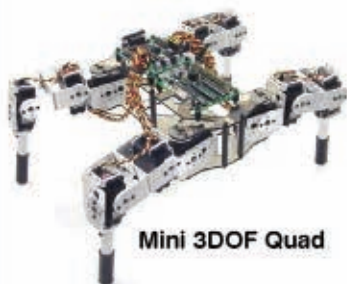
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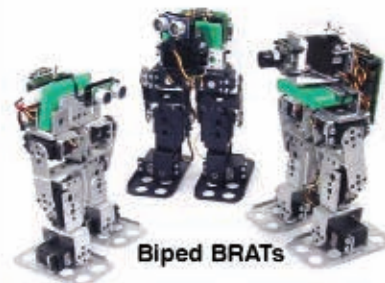


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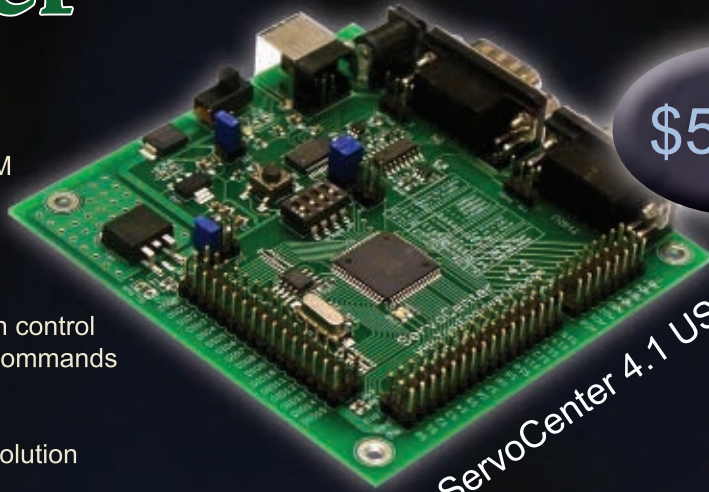
- USB, RS232, and TTL serial support
- 16 servos, 16 digital I/O, 8 analog inputs
- Built-in SC-BASIC Sequencer with EEPROM
- Sequencer allows stand-alone operation
- 64 scene presets stored in EEPROM
- Presets instantly loaded or cross-faded
- Built-in configurable smoothing algorithm
- Independent, simultaneous speed & position control
- Scaled, percentage, and group movement commands
- Timed movement commands
- Max, min, & startup position settings
- Ultra-precise 0.05425μS jitter-free pulse resolution

Flexibility

- User upgradeable firmware
- Upload your own firmware with bootloader
- Watchdog timer for failsafe operation
- Over-current, over-temperature, polarity protection
- Internal regulator, external power, or battery power options
- Supports 4.8/6.0V regulated servo supply voltages at 5 Amps
- Each digital I/O and analog input has supply pins
- Direct serial, activeX control, or Win32 DLL communication
- Programming examples in 10+ languages
- Windows, Linux, Mac OSX compatible

Free Control Panel Software

- Easy editing and configuration of servo settings
- Configure and set up digital I/O & ADC settings
- Edit scene presets
- Program the SC-BASIC sequencer
- Upload and run your SC-BASIC programs
- Debug & communicate with terminal window



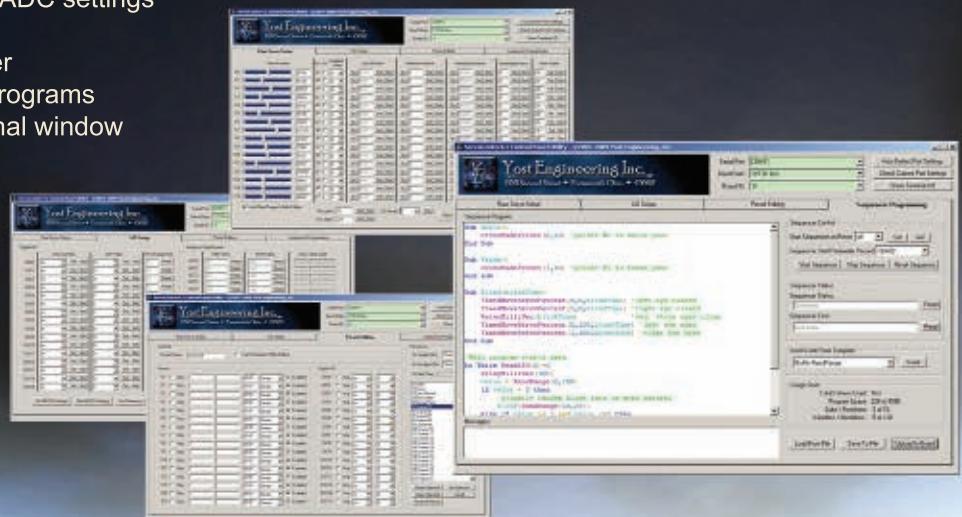
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